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Metal PROGRESS

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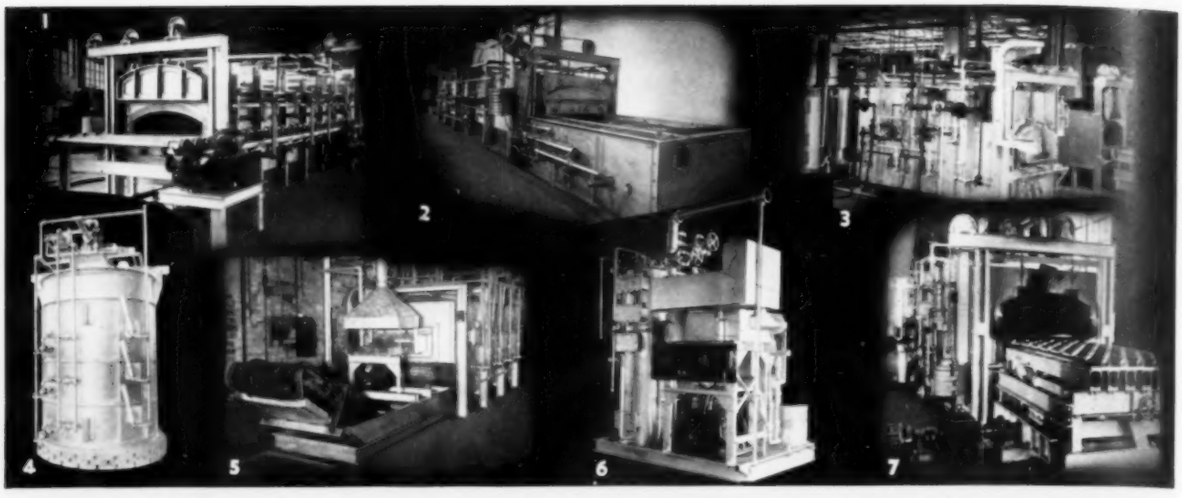

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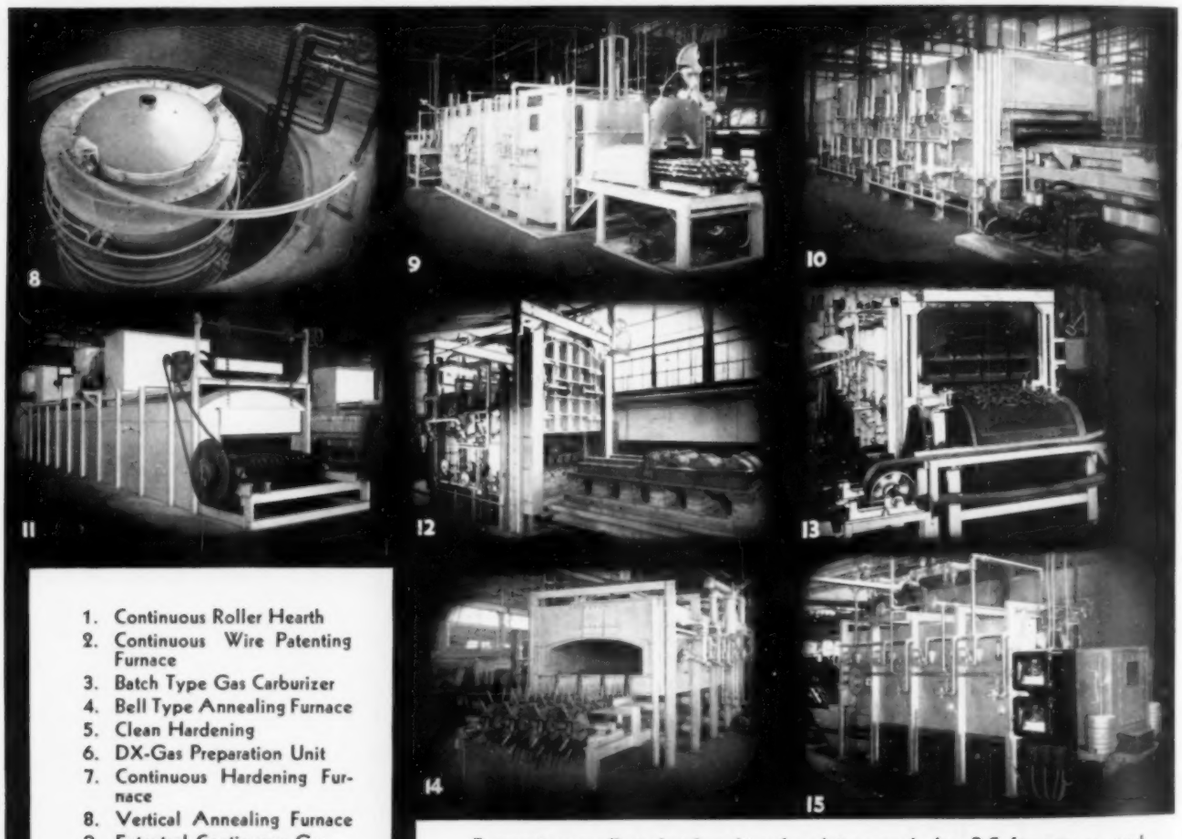

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METAL PROGRESS

Vol. 28 *July, 1935* *No. 1*

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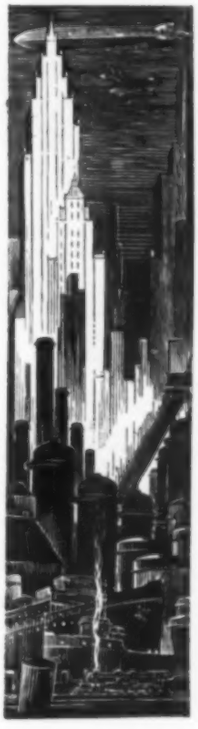

One who attempts to follow the current technical literature, either from duty or from habit, should be interested in the matter starting on page 60 of this issue. It will direct him to articles appearing during May. If he is attracted by any title or author, he will then dig up the original article and read it.

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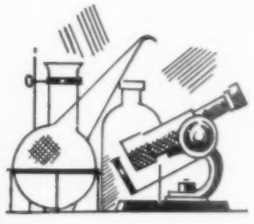

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Free Cutting Aluminum Screw Machine Stock

FREE CUTTING is a term coined, probably by the producers of certain products, to describe a specific combination of properties of metal which make it peculiarly adapted to use in the highly intricate mechanisms known as screw machines. The screw machine has seen much development, both in design and application, from the original screw-cutting machine, designed principally for the production of bolts from continuous lengths of rod. The stationary V dies of the old machine have been replaced by rotating collets, and the opening die head has been replaced by a multitude of tools, the functions of some of which are far from the mere cutting of threads. On the original machine, the cutting tools were mounted on the main spindle and rotated while the stock was stationary. In the machines of today the spindle carries the work, the number of spindles varies up to five or six and the tools themselves may be stationary or may also rotate.

The complexity of the modern machine is illustrated by the picture on the next page. The relatively small space in which the products are formed, together with the high speeds used, are reasons for the development of materials for this specific service. It is obvious that, for maximum production, chips must be small and fall away from the tools readily, in order to prevent fouling of tools and work. In view of the complexity of the tooling, it is essential for economical production that the rate of wear on ordinary cutting materials be sufficiently low so that tools need to be redressed only at infrequent intervals. Also, since the parts are generally in a finished condition as they come from the machine, excellent surface appearance is desirable. Free cutting may, therefore, be defined as "that combination of properties of metal which will permit machining at high rates of speed, with tools having relatively large entrant angles, to excellent finish."

Such requirements led to the development of leaded brass screw machine rod. This material (containing substantially 60 to 63% copper, about 3% lead, remainder zinc) has met these requirements so well that the availability of leaded brass is undoubtedly to no small degree responsible for the present state of development of the screw machine. High-sulphur, low-carbon, cold drawn steel was marketed to make available for screw machine use a free cutting ferrous material. Although this type of steel is much more free cutting than ordinary low-carbon steel, it is not nearly as satisfactory from the standpoint of free cutting machinability as leaded brass.

It probably should be emphasized that the suitability of a material for screw machine production is not necessarily a criterion of its general machinability. Many materials not particularly adaptable for high speed screw machine

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and W. A. Dean
Aluminum Co. of America
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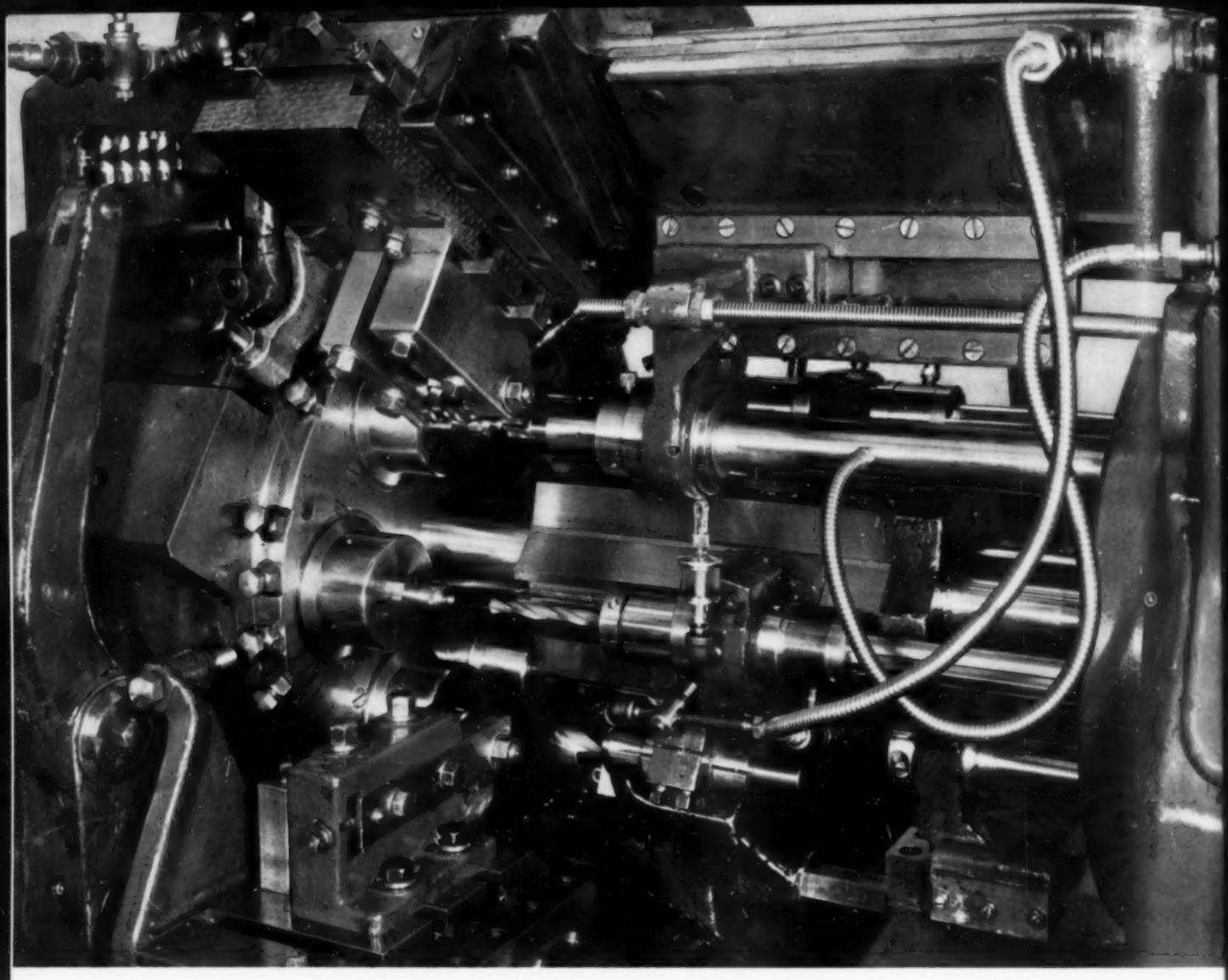


Tool Zone of a Modern Multispindle Screw Machine. Courtesy National Acme Co.

production are eminently satisfactory for general machining operations. All discussion in this article of machinability and cutting characteristics is therefore limited specifically to screw machine operations. Every new type of metallic material is appraised early in its history as to its adaptability for screw machine production, and special modifications may be developed for this particular use. An example is the recent introduction of relatively free cutting stainless steel.

Commercially pure aluminum is not adaptable for general use in automatic screw machines, but it was found with the advent of the high strength, heat treated alloys that these materials had, to a considerable degree, some of the properties desirable for the production of parts in screw machines. A technique was developed and has been in use in the plants of the Aluminum Co. of America which greatly reduced the difference in machining costs between free cutting brass and the heat treated, strong aluminum alloys. In favorable cases this difference may be negligible, but in the general run of screw machine work the cost of machining parts from most aluminum alloys is higher than that of machining them from free cutting brass.

We therefore have long recognized the desirability of a more freely cutting aluminum alloy. The problem has been given much consideration and periodic attempts have been made to develop such material. Some of the earlier ones involved attempts to add lead to aluminum-copper alloys. These experiments met with failure on several different occasions. During some of these trials it was demonstrated that lead-free alloys sufficiently high in copper, say 8% or above, machined fairly well. These alloys could not, however, be commercially hot-rolled to rod because of hot shortness associated with the high alloy content. It was also found that the addi-

tion of tin in certain concentrations would impart free cutting properties to some of the heat treatable wrought alloys. The presence of tin, however, in amounts over about 0.5% so impairs their hot working characteristics as to render impractical the economical production of screw machine stock from them.

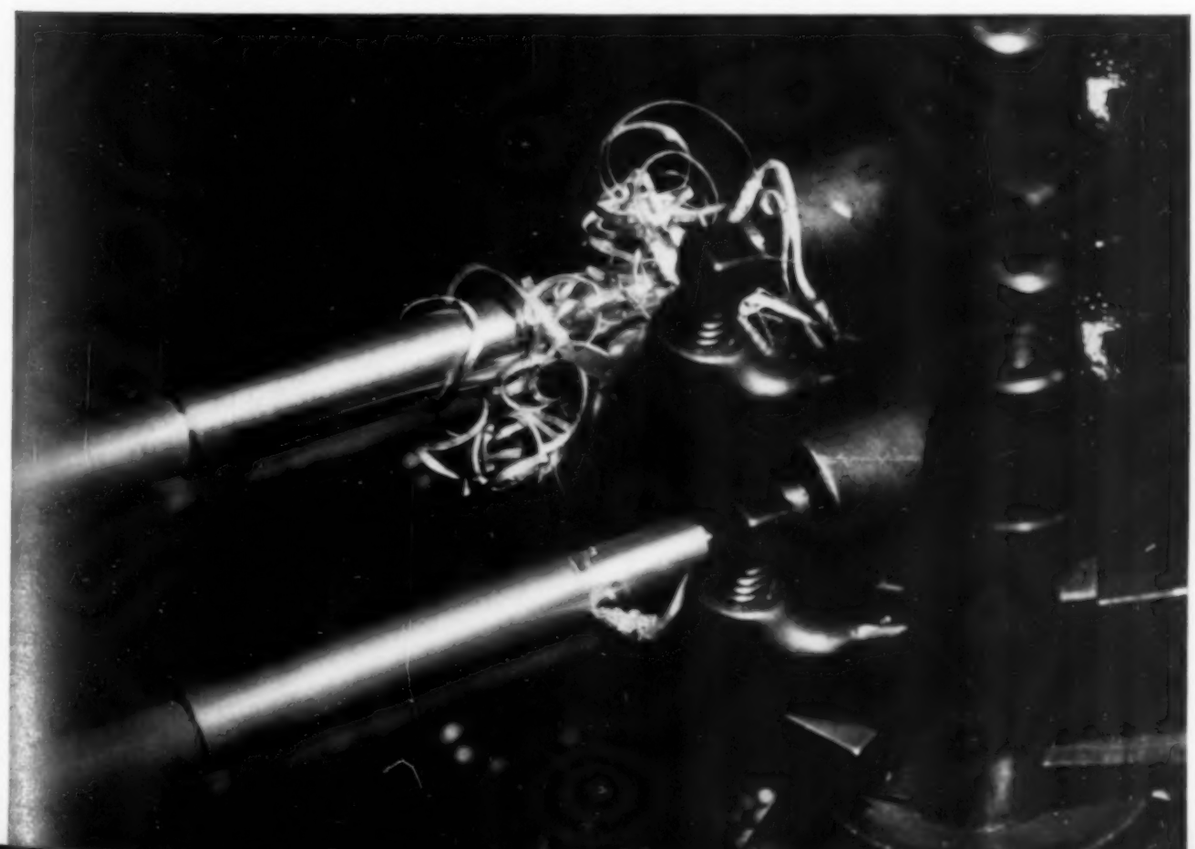
A history of all the attempts to develop a free cutting aluminum alloy might be interesting but has no place here. Suffice it to say that the research was again taken up some time ago. After several futile attempts and disappointments, new alloys were finally discovered and produced which were actually free cutting. Moreover, commercial methods of producing such alloys were developed. Many of the difficulties encountered resulted from the necessity of simultaneously satisfying the several requirements regarding mechanical properties, hot and cold working characteristics, amenability to heat treatment, and corrosion resistance, in addition to the attaining of free cutting characteristics.

Incorporation of Lead

In the course of the investigation, an occasion arose to flux molten aluminum with various lead salts at relatively elevated temperatures. Subsequent analysis of the metal showed the presence of lead in such concentration as to indicate quantitative reduction of the salt, and solution of the reduced lead in the liquid metal. In view of the general opinion that lead was insoluble in liquid aluminum, it was first thought that its introduction as a salt was the best procedure for production of alloys with high concentrations of lead. This was later found to be a misapprehension and it was only after considerable research that the optimum conditions for the alloying of metallic lead and aluminum were worked out, and the solubility of lead in liquid aluminum under various conditions established. Lead added to certain of the common strong aluminum alloys was found to give them free cutting characteristics.

A few words regarding the methods used in evaluating free cutting properties might not be amiss. After much consideration of means of quantitatively measuring tool wear, power to remove a unit volume of metal, and other methods used by investigators in other places, it was decided to confine the initial evaluations to an examination of chip size and finish, using a lathe tool which would give long continuous chips and a relatively poor finish with most of the wrought aluminum alloys which might be adaptable to screw machine production, but small, well broken up chips and a good finish with free cutting brass. The essence of the idea is contained in the cut below, which is a composite photograph of tests on two materials differing in size of chip and finish about as much as

Test Set-Up for Determining Cutting Characteristics. Non-free cutting aluminum alloy (upper) and free cutting aluminum alloy (lower). Lathe cutting tool is used on ¾-in. stock



Various Estimates of Machinability

Alloy	Pressure on Cutting Tool (After Boston)	Energy to Remove One Chip	Nature of Chip	Number of Saw Cuts
X A 11 S-W	100 (basis)	100 (basis)	Free cutting	19
X A 11 S-T		107	Free cutting	19
X C 18 S-W			Free cutting	25
X C 18 S-T			Free cutting	26
17 S-T	116	116	Long turnings	29
Leaded brass	100	114	Free cutting	17
S.A.E. 1112			Short turnings	48
Bessemer screw stock			Long turnings	46
60-40 brass			Long turnings	50

could well be imagined.

It was recognized, of course, that such an arbitrary method of evaluation could not indicate quantitatively the performance of a material in all the variety of operations on a screw machine. It could only be hoped that the indications obtained with the simplified set-up would be modified in degree only, and not in kind, when the alloy was put into actual screw machine operations. Subsequently, this assumption proved in general to be true; a material that gave fine, well broken up chips in the test performed similarly in the screw machine, although marginal alloys in critical operations might show a reversion to a long, stringy chip even though the test indicated fairly satisfactory free cutting characteristics. Subsequent measurements of the energy required to remove a single chip made by means of a specially adapted Charpy impact machine, measurements of the pressure in a dynamometer tool, as proposed by Boston in METAL PROGRESS, Sept. 1932, and Croft's sawing test (wherein a high speed hack saw, 1x0.065 in., 10 teeth, power driven, cut through a ¾-in. bar and the number of strokes were counted) indicated that chip size was a much better criterion of free cutting properties than power or tool wear measurements. Some of the results are given in the accompanying table. We discovered that chip size was an excellent indication of finish as well, for the finish improved as the chip size decreased.

A method now being available for producing free cutting aluminum alloys, it was found that the concentration of lead required for the development of satisfactory machinability in the commonly used strong alloys was too high for the practical production, at the present time, of ingots uniform in chemical composition. Even small ingots which were of fairly uniform composition were found to hot work with difficulty.

The continuation of the story is too long to narrate in detail. It will suffice to state that painstaking investigation was rewarded by the discovery that the simultaneous presence of small concentrations of a multiplicity of elements, found separately to confer free cutting properties on strong aluminum alloys, was much more efficient in producing satisfactory machinability than any one alone! Of a number of elements available for the purpose, lead and bismuth were found to be most practical. Their presence has a relatively small effect on the other properties of the alloy. Advantage was also taken of the effect of copper on machinability, and the concentration of the latter element was placed at about the maximum for satisfactory hot working of ingots.

One of these alloys has been designated XA11S and its mechanical properties are to be found in the second table. In the "T" temper ("T" signifying the application of both solution and precipitation heat treatments) the tensile properties do not differ greatly from those of such well known alloys as 17S-T (duralumin) or free cutting brass. In the "W" temper (solution heat treatment only) there is provided a relatively soft material of excellent machinability which can be cold worked satisfactorily.

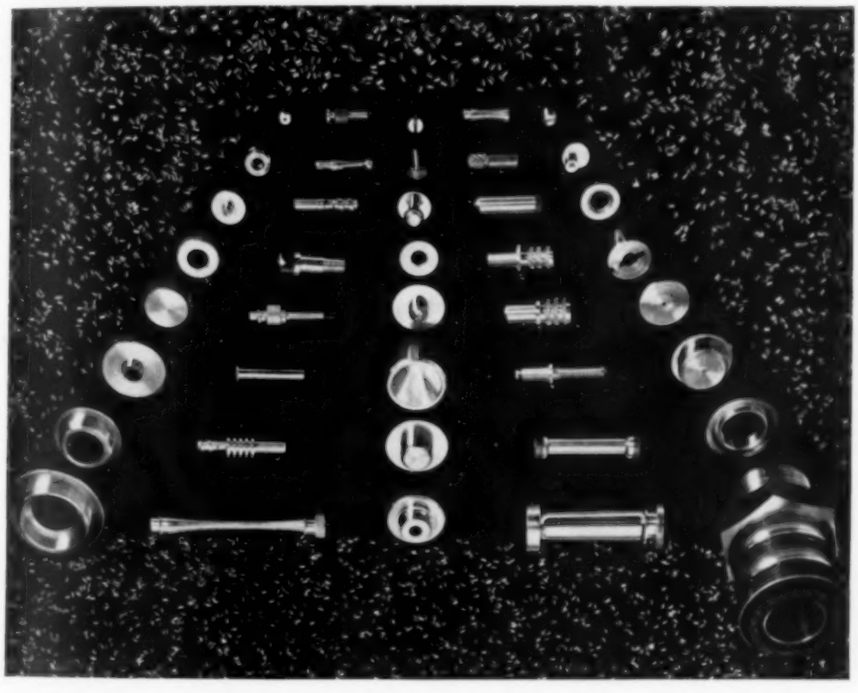
Typical Properties of Alloys Used for Screw Machine Stock

Alloy	Tensile Strength	Yield Strength	Shear Strength	Elongation in 2 in.	Charpy Notch Impact	Brinell Hardness
X A 11 S-W	46,000	32,000	32,000	24%	17.0 ft-lb.	75
X A 11 S-T	55,000	35,000	39,000	23	5.0	100
X C 18 S-W *	52,000	31,000	35,000	22	7.3	95
X C 18 S-T *	60,000	48,000	40,000	14	3.5	135
17 S-T	56,000	34,000	37,000	23	9.5	100
Leaded brass	60,000	44,000	40,000	16	10.0	125
Steel, S.A.E. 1112	97,000	91,000	62,000	13	13.7	200
High sulphur, cold drawn, Bessemer steel	89,000	86,000	57,000	14	13.5	190

* Tentative figures, probably conservative

The wide range of mechanical properties undoubtedly offers opportunities for broad application and improved products.

The laboratory work having indicated a promising composition, it then became necessary to determine the fabricating characteristics in large scale production. Making a commercial ingot of uniform chemical composition, from an alloy containing considerable quantities of heavy elements having very low or substantially no solid solubility in aluminum, proved to be a task very different from that of producing small ingots under laboratory conditions. The problems of alloying and casting were successfully overcome, however. Hot rolling and drawing presented no great difficulty, fortunately, and rod was soon available for trial. It was then found that the alloy was much more free cutting than the aluminum alloys previously used for the production of screw machine parts, and work was initiated to develop a technique to take advantage of the potential economies it offered.



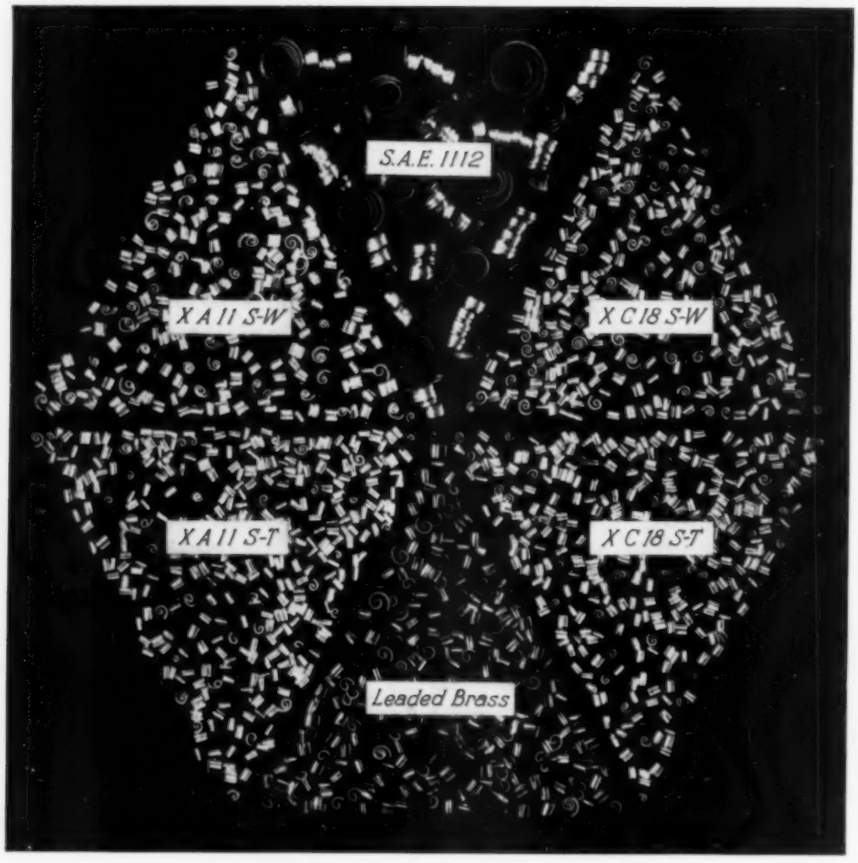
Screw Machine Parts Produced From Free Cutting Aluminum Alloy Stock

The relatively low yield strength of the alloy in the "W" temper (solution heat treatment only) offered the possibility of cold working operations after machining, although at the same time it presented the problem of bending such plastic metal during its machining. It was found that deformation and consequent breakage during machining could in most cases be overcome by slight changes in tool design. The fitting for non-metallic, flexible tubing shown in the lower right corner of the view on this page, is an example of severe cold forming after machining, for the fitting is finally crimped onto the flexible tubing. The "T" temper of the alloy (precipitation hardened) has the advantage of higher yield and shear strengths but somewhat lower impact resistance. The relatively low degree of toughness, evidenced by the last mentioned property, in some set ups appeared to be responsible for breakage during machining. A careful examination of the new alloy XA11S in both tempers by the staff at our Edgewater Plant (specializing in screw machine products) led to the conclusion that an alloy with a toughness corresponding to an impact resistance of 8 or 10 ft-lb. and the cutting properties of XA11S-W would make a desirable addition to the free cutting alloy field.

Thereupon the laboratory took up the work of developing this required type of material. It was found that alloys which develop their optimum properties on aging at room temperature are generally tougher for the same tensile strength than alloys which are aged at elevated temperatures. Magnesium was added to XA11S to induce aging at room temperature. Surprisingly enough, however, the free cutting properties of the resulting alloy were somewhat diminished. Considerable investigation was necessary before finding that the addition of certain alloying elements again restored the desirable cutting characteristics. One of the alloys of this type has been designated XC18S. It will be seen from the table of mechanical properties that this alloy in the "W"

temper has properties comparable to those of 17S-T (duralumin) and free cutting brass, both as regards strength and toughness. In the "T" temper, involving aging at slightly elevated temperatures following a solution heat treatment, very high yield, tensile and shear strengths are obtained at the expense of some elongation and toughness.

Plant trials of XC18S-W confirmed the greater toughness indicated by the relatively higher impact resistance. In short, the alloy seems to possess an all-round adaptability superior to XA11S, and cutting characteristics only slightly inferior.



Comparative Size of Chips From Various Materials Used for Screw Machine Stock Produced in the Test Set-Up Shown in the Second Photograph

Availability of New Alloys

It is, of course, desirable that the number of alloys stocked in local warehouses in the form of screw machine rod be kept at a minimum. The tables list two free cutting aluminum alloys, each in the two different tempers "T" and "W." It is obvious that complete stocks of all four materials cannot, with the present volume of business, be maintained at a large number of distribution points. It is therefore to be hoped that one temper of one of these alloys will be found satisfactory for the majority of screw machine production. On the other hand, sufficient data regarding the performance of these materials under production conditions are obtainable only by trial in a variety of commercial plants. Also, it is not yet possible to decide which of these materials will be the most economical to fabricate. We have therefore considered each application separately; making what seems to be, on the basis of the available data, the best recommendation of a material for the particular job under consideration.

Considerable experience has already been accumulated in connection with these materials; XA11S, particularly, has been used in considerable quantities for several screw machine applications, some of which are shown in the photograph on page 25. In applications such, for example, as the counter wheel (third piece from

the bottom, left hand row), the free cutting aluminum alloy rod has replaced the free cutting brass rod with no change in machine set-up, speeds, feeds or tool angles. The detail of this set-up is as follows and indicates that these new alloys are capable of adapting themselves to extremely high speed production.

Stock: Free cutting aluminum alloy, 1.008 to 1.014-in. round.
Machine: Brown and Sharpe, high speed.
Spindle Speed: 3000 r.p.m.
Tools: High speed steel.
Production: 600 pieces per hr.

Feeds:		
	Spot drill	0.0121-in. per rev.
	Drill	0.0214-in. per rev.
	Counterbore	0.0032-in. per rev.
	Ream	0.016 -in. per rev.
	Knurl	0.0032-in. per rev.
	Form	0.0029-in. per rev.
	Cut-Off	0.006 -in. per rev.

In other jobs it has not always been possible to maintain exactly the same tool set-up as used for free cutting brass, largely because of stock breakage. In such cases it has generally been found that the trouble can be eliminated by slightly increasing the rake and clearance of the tools to about the angles used for steel screw stock. On the other hand, it has been found that in replacing 17S-T with these free cutting alloys, the acute entrant angles necessary to machine the former may cause the tools to bite in so deeply that breakage of the tool or work occurs. This has been eliminated by reducing clearance and rake angles. In general, the tool wear appears to be slightly higher with these free cutting aluminum alloys than with free cutting brass. Tool life is, however, better than that obtained with steel or duralumin screw machine stock.

Comparison With Older Materials

A number of attempts have been made to evaluate in a quantitative manner the machinability of these new materials as compared with the older steel and brass screw machine rod. The first table gives some of these comparisons utilizing three different methods of testing. It will be noted that the free cutting aluminum alloys are quite comparable in machinability to the older screw machine materials. It must, however, be emphasized that no two metals are exactly alike, and the maximum economical return can be achieved only by recognizing the peculiarities of each material and by taking advantage of its favorable properties. Thus, for example, although the tool wear with these free cutting aluminum alloys may be somewhat higher than for free cutting brass, nevertheless, their low density frequently makes possible higher speeds or a lower rate of deterioration of machines at existing speeds.

Applications

It is not to be assumed that the alloys of which XA11S and XC18S are examples will displace all the previously used aluminum alloys from the field of screw machine products. Thus, the long history of 17S-T in various structural applications and its position in approved specifications will be responsible for its continued use in many places. Also, since application requirements are almost infinitely varied, it is to be expected that in many instances it may be economical in the long run to utilize materials of inferior machining characteristics because optimum service qualities may not be available in alloys possessing maximum machinability. Thus, the resistance of different alloys to deterioration by corrosion varies greatly with the application environment, and it is obvious that in some cases machining characteristics must be subordinated to corrosion resistance.

On the basis of a few accelerated laboratory tests, the corrosion resistance of the new alloys XA11S and XC18S in the "W" temper appears to be comparable to that of 17S-T. The application of precipitation hardening treatments to put the alloys in the "T" temper seems to result in a slight decrease in corrosion resistance. Even in this temper, however, the corrosion resistance is comparable to that of other aluminum alloys which have been used in large tonnages.

These new alloys offer many opportunities for the economical production of parts for a wide variety of structural assemblies. They are tarnish and corrosion resistant, and in their natural finish possess a pleasing white color, adapting them to modern color schemes. The machined part may be anodized and the oxide coating thus formed may be colored as desired. In common with all aluminum alloys, these materials have the low densities particularly desirable in moving parts. The photograph on page 25 illustrates a number of articles produced from these materials by various large producers of screw machine parts.

It is hoped that these metals will find economic justification for their existence by supplying a material whose properties will fill the requirements of some applications better than any other substance.

This combination of alloys acts primarily by strengthening the ferrite, hence is free from changes in hardness by carbide action during air cooling from normalizing, flanging or welding heats. Mr. Miller develops the commercial consequences of these metallurgical facts.

Alloy Sheet Steel

(Copper-Nickel-Molybdenum)

IT IS WORTHY of remark that, after low carbon bessemer steel had been established as the superior of the ancient wrought iron for most structural and machine work, the efforts of metallurgists were concentrated on methods (principally of alloying and heat treatment) that gave steels having on the order of twice its strength and hardness. Achievements in this line have been exceedingly great since the turn of the century. Only in comparatively recent years have steels falling within the gap between ordinary carbon structural steel and the S.A.E. alloy steels been studied.

Doubtless the economic conditions since 1929 have had much to do with this renewed attention to the problem. For it is not a new problem, by any means. It had been met by bridge engineers in the construction of very long spans, and solved by them either by the use of a 3½% nickel alloy steel, or by strengthening the common structural steel with a little more of the elements already there, namely, carbon, manganese, and silicon. It should be emphasized, however, that for nearly all static structures unalloyed mild steel is quite adequate. Only in the unusually large or special work would its weight commence to be an uneconomic factor. Its principal deficiency as made today is a low and variable true elastic limit (which means that designers figure it for a small percentage of its ultimate strength) and poor resistance to corrosion (which means that parts carrying low stress must be made fairly thick to allow for rusting).

It is rather that a new aspect of the old problem has been emphasized by recent economic conditions. This has focused attention on the cost of moving dead weight — on the savings to be made by taking pounds off of moving structures. Of course, a clear-cut situation exists in aircraft, but even automobile engineers are not yet agreed upon the relative merits of, say, aluminum vs. cast iron pistons. Hence it is not surprising that marine designers, railroad men, and makers of machinery in general, have been slow to admit that enough cheap steam or electric motive power could be saved to pay even a moderate premium for lighter weight in moving parts. Probably the designers of ships would still be unimpressed were it not that the various navies have used high strength steels in new vessels meeting treaty limitations as to displacement.

A combination of factors has brought this matter to the attention of the railroads. Cost of coal is rising, and no end is in sight. Size of locomotives and length of trains has about reached the limit; consequently savings in operations must come through more economical use of power. Savings in maintenance can be made by building or rebuilding with more durable (rust resistant) materials. Two of the most important factors in the vanishing profits in rail-

By Howard L. Miller
Metallurgist
Republic Steel Corp.

roading are the large weight as compared to the paying load, and rapid deterioration.

Hence the interest in light weight permanent construction of rolling stock, involving, as it does, increased proportion of pay load, higher speed, decreased maintenance, and longer life. The experiments made recently in using steels of special analysis or aluminum alloys in the construction of passenger and freight cars indicate that railroad men are actively seeking some way to improve the position of their industry by decreasing weight as well as by increasing performance. The steel industry, on its part, has ready for its largest customer — the tranportation industries — a series of low alloy steels suitable for this new demand, stronger and more corrosion resistant, and yet but little more expensive than the common mild steel. They occupy, in fact, the gap formerly existing between the plain and the alloy steels.

The contribution of Republic Steel Corp. to this vital and pressing need has been the development of a copper-nickel-molybdenum steel which offers a combination of high strength, workability, and resistance to atmospheric corrosion. Its nominal composition limits are as follows: Manganese 0.50 to 1.00%, copper 0.50 to 1.50%, nickel 0.40 to 0.80%, and molybdenum 0.20 max. It is made in two grades, one with 0.12% max. carbon, the other with 0.30% max. carbon. Yield point of either grade is about twice that of carbon steel sheet or thin plate, made and normalized in the same way, and hence these new steels are called "Double Strength Steels."

Let us now discuss the three principal qualifications for such improved steels: *(a)* Strength, *(b)* workability, and *(c)* corrosion resistance.

First, as to strength — which also implies a high yield point and endurance. It is desirable that the ultimate strength of the metal *in the structure* should be relatively high so that the endurance against fatigue stresses shall be correspondingly high. Endurance limit is usually about half the ultimate strength, and design stress in turn is about half the endurance limit. Hence a high ultimate strength means a correspondingly high safe stress in design. High yield point is also desirable, because it guards the structure against permanent deformation on accidental overload. A high strength and a yield point equaling 80% of this ultimate strength are characteristic of many alloy steels in the quenched and tempered condition.

However, in our development we desired to avoid a *heat treated* product, principally because the inevitable welding would destroy the acquired properties alongside the joint. Furthermore, alloy steels that may be hardened by quenching will also air harden when in relatively thin plate or sheet form, and this is to be avoided as a manufacturing condition in sheet and strip for the reason that different gages rolled from the same heat when cooling in air from the normalizing furnace will show considerable difference in physical properties. We also had in mind the psychology of designers and maintenance men in the mechanical and transportation industries — whether they realize it or not, their thinking and most of their actions are based on the properties of iron (that is, ferrite) rather than of steel.

Hence our effort was to improve the properties of ferrite in the new material, rather than to make just another perfected alloy steel.

Strengthening the Ferrite

The metallurgist has a wide choice of alloying elements for raising the physical properties of the simple iron alloy known as structural steel. While their mutual reactions are somewhat complex, and the final result is influenced greatly by grain size, these elements fall into two groups or broad classifications with regard to the nature of their strengthening effect. The first of these groups is called the carbide formers; they strengthen an alloy primarily by influencing its properties after heat treatment. The second group contains alloys that affect the strength of the ferrite. The common and relatively inexpensive elements may be divided thus:

Carbide Formers	*Ferrite Strengtheners*
Carbon	Copper
Manganese	Nickel
Chromium	Molybdenum (in small amounts)
Silicon (in excess)	

It is obvious that our efforts should be directed toward the metals in the right-hand column. Fortunately we in the Republic Steel organization have had many years' experience with these very ferrite strengtheners in our material called "Toncan Iron," a low carbon open-hearth iron to which is added at least 0.40% copper and 0.07% molybdenum. This is one of the best of the corrosion resistant materials (short of the very high alloy stainless steels) and hence has the basis of the third requirement stated for the new material, namely, durability. We had also long been studying the effect of various proportions of copper, molybdenum, and

carbon, as well as combinations of other alloying elements on this base composition, and so had a good background of manufacturing experience, laboratory studies, and exposure tests. We therefore were not averse to using copper as an alloying element, knowing that very tough copper steels could be made, despite the unfounded prejudice against them. Even with this background it has required a series of experimental heats and a 2½-year investigation to perfect a balanced analysis and suitable steel making technique.

Dr. Lorig has printed an article summarizing the effect of copper when alloyed with steel in METAL PROGRESS as late as the April issue, so there is no need to restate the details. He shows that copper up to 2% has the property of increasing the ultimate strength, yield point, and hardness in normalized samples without changing materially the ductility (as measured by elongation and reduction of area) and at the same time improves the toughness (Charpy impact values). Certain steel mill difficulties are cured by adding about half as much nickel as copper, and nickel, as is well known, has a long-established and deserved reputation for strengthening and toughening the ferrite. Finally, molybdenum is added for two important reasons — first it produces a fine grain structure in the normalized sheet and second because it seems to have some influence in keeping an excess of copper in solution in ferrite over the amount indicated in the equilibrium diagram. Hence we arrived at the base analysis mentioned above around 1% copper, 0.5% nickel, and 0.20% molybdenum. Manganese is kept on the high side of the ordinary analysis, in keeping with the modern trend in first-class steel making practice. Physical properties of the two grades in normalized condition are shown below.

Physical Properties of Cu-Ni-Mo Steel

	Low Carbon		Medium Carbon
Carbon	0.08%		0.23
Manganese	0.70		0.75
Copper	1.40		1.30
Nickel	0.75		0.75
Molybdenum	0.11		0.16
Form :	14-Gage Sheet	½-In. Plate	Thin Plate
Ultimate strength	80,000 psi.	74,000 psi.	90,000 min.
Yield point	70,000 psi.	65,000 psi.	70,000 min.
Elongation in 2 in.	30%	50%	20%
Elongation in 8 in.		31%	
Izod impact		76 ft-lb.	50 ft-lb.

For comparative purposes it may be stated that without the copper, nickel, and molybdenum addition, this carbon and manganese would not show much over 32,000 psi. yield point and 52,000 psi. tensile strength in the ½-in. plate, and 38,000 psi. yield point and 56,000 psi. tensile strength in the normalized 14-gage sheets. It is apparent, therefore, that we have achieved the desired strengthening in the new material. Let us see how this enables the designer to save say 33⅓% of the weight of a moving structure.

Common practice is to design to a unit stress of 16,000 psi. and to use 32,000 psi. as the yield point for structural grades of steel. This is a relationship of one to two. With increased speeds the kinetic energy increases in the order of the square of the velocity and it is recommended that for safety's sake the factor should be increased to at least one to 2½. That means that the material should have 40,000 psi. yield point for the same 16,000 design stress. On this basis, a high speed member reduced one-third in thickness would carry around 24,000 psi. unit stress, and a minimum yield point of 60,000 psi. should be required in the metal. On the same basis, a 40% reduction in gages would develop 26,600 psi. working stress and material with a minimum yield point of 80,000 psi. These yield points (and several even higher) are being commercially produced in "Republic Double Strength Steel," and are being applied in various forms of transportation equipment. Some of these units have already been in exacting service for more than a year with complete satisfaction.

So much for the first requirement of a new structural material. The second main requirement listed is workability. This is usually measured by ductility in bending. Deficient ductility of this sort prevents the adoption of the simple higher carbon steel for strength members.

The copper-nickel-molybdenum steels described may be bent easily hot or cold, without cracking. For instance, the medium carbon alloy in ½-in. plate can be bent to 90° with radius of bend equal to thickness of plate. Light gage sheet in the soft (low carbon) analyses can be bent cold, flat upon itself, either parallel to direction of rolling or perpendicular thereto. This means that the material works well in forming dies, punch presses, and bending brakes, being free from work hardening or air hardening (if bent or flanged hot).

A second requirement under workability is weldability. The modern trend toward welding as a method of joining relatively thin metals is

based on sound engineering, for it is difficult to make satisfactory riveted joints in such material. Rivets are points of stress concentration — a bad condition when members are already designed for high stress. Rivets are also centers of corrosion. In addition to this, light sheet has deficient stiffness for tight seams.

In order to fabricate satisfactorily large sections which cannot be annealed or heat treated after welding (especially after repair welding in the field), it is necessary to have a high strength material which does not air harden.

Drawing by Otto Kuhler of "Milwaukee" Type Steam Locomotive. (*Courtesy American Locomotive Co.*) *It hauls de luxe, high-speed, stream lined train between Chicago and Minneapolis, 410 miles and 5 stops in 390 min.*

"Republic Double Strength Steel" has little tendency to air harden, and is very adaptable to fusion welding. It can also be satisfactorily spot welded and resistance welded. With the proper welding wire and procedure, tough, strong welds are readily produced. Material under 18-gage would ordinarily be spot welded, as it is too light to weld satisfactorily with the arc. No difficulty is encountered in welding the heavier gages. Microstructure, hardness, toughness, and corrosion resistance are not changed appreciably by welding or any other heating operation.

However, this requires a steel made with special attention to several factors, and the practice has fortunately been well worked out in alloy practice. Weldability requires a killed steel, in the sense that no gases are evolved from the melted puddle, causing "arc blow" and porosity in the completed joint. Toughness and stability after various heating operations require a very fine grain size (7 to 9 on the A.S.T.M. rating), and a structure that will coarsen no lower than 1900° F., thus giving a safe surplus above normalizing heats.

Finally in regard to corrosion resistance — that is, durability — it should be pointed out that these new steels contain the highest copper in any commercial rolled product. Likewise, that of all the controversial facts concerning corrosion resistance, the least debatable is the surprising ability of copper to convert a rapidly rusting steel into one that resists atmospheric corrosion excellently. This has been established without doubt by the impartial and extensive exposure tests made by the American Society for Testing Materials. Dr. Lorig's article may also be quoted: "Resistance to corrosion continues to increase above 0.50% copper, when it is retained in solution in the ferrite," and he cites experiments on air-cooled sheets containing up to 1.0% copper. It is significant that copper-nickel-molybdenum steels acquire an exceedingly tight oxide skin under exposure to the most severe industrial atmosphere, and for this reason are particularly advantageous in railroad and automotive truck equipment used in carrying coal and other corrosion-promoting products.

Age Hardening Effects

It is believed that the copper steels have many potentialities not existing to any marked degree in other alloys, and that is the ability to harden after a low temperature heat treatment. They are a variety of the age-hardening alloys discussed by Dr. Merica in his series of articles now running in METAL PROGRESS. They will therefore be watched with considerable interest by the metallurgical world in general. The tensile properties of the two grades as noted in this article can be increased 15,000 to 20,000 psi. by tempering sheets at 900 to 1000° F. for about one hour. The commercial value of these higher properties is somewhat problematical, but may be expected to have important applications in high strength weldings.

Take, for instance, light-weight truck frames or mobile artillery mounts. These may be made of alloy steel castings, but the foundry difficulties in making walls and diaphragms thin yet quite sound are great, to say *(Continued on page 70)*

The author speaks from long experience in the manufacture of flat ware and domestic cutlery. Difficulties arise from a variety of causes, in the design, in the tool room, in the steel, in the heat treat, and in the production machines

Die Failures
Their Diagnosis and Cure

SINCE every manufactured article in our modern civilization is the product of steel tools or dies, it is obvious that "defective tools" (the subject of this article) covers a multitude of considerations. However, the subject is important, not only because the investment in tools and dies is an important sum in any plant, but because the success of the enterprise from a financial viewpoint frequently depends upon the proper performance of the tools.

The writer has observed that nearly everyone coming in contact with a broken punch or die is more than willing to tell why it broke! This may not be altogether a wrong thing to do, as long as the metallurgist looks upon them as theories or suggestions, and does not accept them as facts unless careful analysis indicates their inherent probability. Likewise it is true that much depends upon the size and shape of the tool itself and much more upon the machine tool in which it operates, so that the cure for a certain trouble in a small sinking die may not be the cure for a closely similar trouble in a somewhat larger blanking die. Therefore in discussing this subject it is my purpose to describe particular tools, and explain some of the conditions responsible for such failures — or at least those conditions which when corrected permitted future satisfactory performance.

By Luther H. Williamson
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Chicago

For a more reasonable understanding of the subject, it is well for the reader to bear in mind that high carbon tool steel (the material used, unless otherwise noted) is shallow hardening — that is to say, the rate at which austenite transforms into pearlite is so rapid that only a relatively thin shell on the outside can be prevented from transforming by even drastic quenching in brine. Also that the deeper seated portions of the hot steel block or tool cool at a progressively slower rate, so that very large stresses are set up by the more rapid shrinking (during cooling) of the outer regions on the less rapidly contracting central portions. And lastly that there is a pronounced expansion connected with the transformation to pearlite during cooling, and an even greater expansion in the arrested transformation to martensite.

The net result of these complicated interactions is that hardened steel is less dense (occupies greater volume) than annealed material. We also have a limited surface layer of martensite firmly attached to a voluminous core of unhardened steel. As martensite occupies a larger volume per given weight than steel in the unhardened condition, it may be safely assumed that the core must remain fixed to this hard, unyielding and forcibly expanded exterior, and a

state of tension must exist between the hard and soft portions and that the soft core will be actually stretched as long as the piece remains safe and sound.

Fig. 1—Die for Forming Bowls in Silver Spoons, Cracked by Incorrect Heat Treatment. Another spoon die had a single crack on knob, caused by mechanical weakness of the hardened surface where it was ground thin to fit gage

One failure that was probably caused by internal strains is shown in Fig. 1. This die is used for forming the bowl in a silver spoon, and is subjected to repeated heavy impacts. It will be noted that the cracks follow nearly straight paths for some distance and then abruptly cut across the corner and follow down to the bottom of the die. It broke almost immediately after being put into service. Appearance of the fracture and its manner of breaking into well-defined pieces, clearly indicates that the source of trouble lies in non-uniform temperature before quenching. It may have been heated at too fast a rate or held an insufficient length of time at temperature; inequalities of temperature in different parts of the piece may have occurred during a delay between removal from the furnace and quenching; strains may have been insufficiently removed in drawing. All of these possibilities would have to be considered before arriving at a correct solution of the trouble.

Partially or completely cooled dies will sometimes break when removed from the quenching tank or while being tempered, whereas if they were transferred from the quench to an oil bath while still fairly warm on the inside and allowed to remain there until quite cold, they would stay perfectly safe and sound.

Another die of this sort developed a single crack across the edge of the polished knob after a very short life; it was also called a "water crack." However, in order for this hardened die to fit the gage properly, it was necessary to grind a portion of the hard surface layer away. The fine crack developed in the midst of the ground area. It seems logical to assume that this crack originated from the inability of the surface layer, when weakened by the removal of part of its mass, to overcome the tendency on the part of the core to change its volume. This cracked the surface of the thinned area, and the crack rapidly extended itself across the face of the die under additional impacts.

Another possibility that could account for a crack of this kind is rash grinding. The heat generated at the point of contact with the wheel would cause this particular local spot to expand suddenly and crack. This was impossible in this instance, however, as the grinding was performed very carefully with a soft, fine-grained wheel, in good condition. It was obvious that the remedy for the difficulty was to perform all grinding necessary *before* hardening; when this was done no further trouble was encountered.

Figure 2 represents a drop forging die which cracked transversely across the approximate center. It was removed from the quenching bath while still slightly warm and promptly placed upon a hot plate for drawing; it broke very

Fig. 2—Drop Forging Die Which Broke Spontaneously on the Drawing Plate. Previous quench was too drastic, considering the mass, shape, and carbon content of the steel

shortly with a violent report and the pieces flew in opposite directions about five feet. There do not appear to be any internal defects. (It is also well known that it is the tendency for a block containing an internal defect to split longitudinally with the direction of rolling or forging and not transversely, as in this particular instance.) It therefore seems that this die broke from internal stress induced by too drastic a quench for the die to accommodate, considering the relation of its surface area to its mass and analysis (carbon content).

From the appearance of the fracture (irregular grain size), the most likely contributing factor is insufficient soaking time at temperature. The consequence is that the block is not heated through and through, and the center is considerably lower in temperature than the surface. This greatly increases the temperature gradient between different parts of the block while quenching, and thereby induces enormous additional stresses and strains. When the block is placed upon the hot plate, the surface begins to expand at a faster rate than the center of the block, and this increases the tension already existent to such a point that it overcomes the resistance of the core and thus the center of the die is actually pulled apart.

Tools of a certain shape, such as cylindrical rolls of unequal cross-section, made from high carbon material and quenched from one definite temperature, may be perfectly sound after tempering, yet they will crack if quenched from higher or lower temperatures and given the same draw.

A 6-in. roll which seems to support this statement is represented in Fig. 3 and 4. While quenching rolls of this design, a strong stream of water is forced through a ⅝-in. hole drilled down the axis. This facilitates a more uniform removal of heat from the roll, and prevents the expansive forces of the hot interior, as it passes through the critical range, from causing rupture. This roll, when quenched from 1575° F., remains perfectly sound after tempering. If the hardening temperature is increased to 1600° F., the sharp corner at the largest diameter of the roll spalls off, as shown in Fig. 3. When quenched from 1525° F., the corner at the extreme end of the small section sheds itself in the form of a complete ring, as exhibited in Fig. 4, at the right, below.

There must exist some critical relation between the depth of hardness penetration and the heat gradient which exists among different sections of the piece while being quenched, and this determines the amount of stress which will develop. When this roll is quenched from 1600° F., the hardness penetration is so deep at the corner of the large diameter, that the metal there is unable to accommodate the stress and tension it is subjected to. On the other hand, the cooling speed through the critical is increased by quenching from a higher temperature and the smaller section at the roll neck hardens clear through, with consequent uniform expansion to the center. In this way, the small section would not shed its corner. It also follows that the effect of a lower quench (1525° F.) would decrease the amount of stress at the corner of the full section, and, by leaving a soft core in the roll neck, enough stress would develop there to cause fracture.

From consideration of these pieces, it might be suggested that it is sometimes advantageous to quench from a different temperature than what is theoretically correct, when we are dealing with a certain design having square corners.

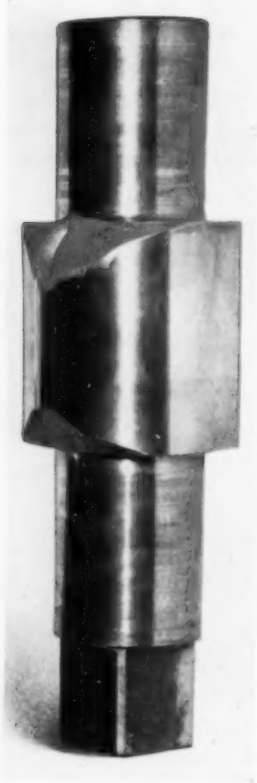


Fig. 3 and 4—Rolls for Cold Mill; One Quenched From Too High a Temperature Whereupon Massive Corners Burst; One From Too Low a Temperature, and Corners of Neck Shelled Off

Now and then one has a failure due to some internal defect in the steel itself. This may be a pipe, an imperfectly welded blowhole, a non-metallic inclusion, or a crushed center due to improper forging. At any such internal defect the metal has only adhesion and not cohesion, and it will not be difficult to foresee that any tension applied to the interior of a die containing such a defect would probably cause breakage in hardening — if not, then certainly soon after being put into service.

One of the most common causes for failure in striking dies is the sinking of the surface at some particular area, thus producing a fine crack adjacent to or completely surrounding the section affected. To develop such fine cracks clearly, the die may be heated slowly in water up to 160° F., and then etched for 30 min. in 1 to 1 hydrochloric acid at the same temperature. It will usually be observed that the crack is along the edge of that part of the die which received the hardest part of the blow. When such a block is cross-sectioned through the crack and similarly etched it will be noticed that the crack extends in a straight line entirely through the hardened zone. Thus a sunk area may be an indication of insufficient hardness penetration, too fine a grain size in the core, thus not possessing enough rigidity, or the die may have been improperly fitted when made. When coining or embossing silverware having a varied or graded thickness along its length, the dies must be fitted to correspond to the blank, so that the force of the blow is applied evenly over the entire surface of the die at the same moment. If this is not done, an exceptionally hard blow is required to planish the ware and produce a clear-cut pattern, and the small area of the die that comes in contact first will be unable to withstand such an impact, and will therefore sink.

In order to overcome sinking, the depth of hardness is increased, either by using an alloy steel or by raising the hardening temperature of the carbon steel block. Higher quenching temperature acts in two ways: *(a)* It coarsens the austenitic grain and coarse-grained steels are deep hardening, and *(b)* it speeds up the rate at which the surface is cooled through the critical range and hence increases the depth of material that cools rapidly enough for martensite to form. However, care must be exercised so that hardness does not penetrate too deeply. If such be the case, minute strain cracks will form in the hardened area of the die. They are readily distinguishable from sinking cracks as they do not extend through to the soft core, but confine themselves to the martensitic section. They will not be eliminated by raising the temperature or lengthening the time of drawing, and will cease to exist only if the depth of hardness is reduced.

Fig. 5—Striking Die Failed After Long Run by Fatigue Crack Starting at Axis.

Figure 5 represents a die which failed after perfectly satisfactory production. This crack originated at the exact axis. It is not due to an axial defect but obviously to fatigue. Any striking die at the moment of impact will bend slightly about the center of pressure and then return to its former position. As the stresses in this die were concentrated in the center of the face, a small fatigue crack started underneath and gradually extended itself to the edges of the block.

Fatigue is also responsible for many failures of punches, only in such cases the trouble is due to the fact that the punch press frame is not stiff enough. The punch, in forcing its way through the metal, causes the main frame to spring slightly, thus "cocking" the punch out of line and throwing heavy bending stresses into it as it goes on through and is pulled back out of the hole. Fatigue cracks in such punches start from the *side* of the tool. Identical tools put into more massive presses with stiffer frames will give satisfactory life.

I have also in mind a punch of high carbon, high chromium steel. A part of the surface flaked off clear across the width of the punch at one end. This difficulty is caused by insufficient clearance in the die and may be easily overcome by either increasing the amount of clearance or by engaging the punch deeper into the die, which, of course, accomplishes the same effect as additional clearance. Occasionally, with hard or thick materials being blanked, the stripper plate will be responsible for this trouble if it does not fit close up to the punch. This particular type of failure is not to be confused with ordinary chipping of the cutting edge, as this is caused

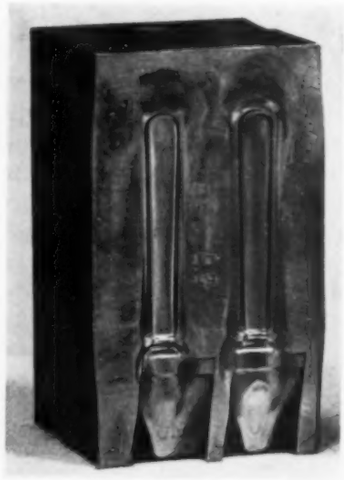


Fig. 6—Breakdown and Finishing Impression in Drop Hammer Die, Badly Worn on One Side. Hammer base was out of flat, and die rocked sideways so that nearly all of the flow of metal was in one direction.

either by the punch being left too hard or by overheating in hardening.

It sometimes happens that one side of the finishing impression of drop forging dies will wear more rapidly than the other side of this same impression. An illustration of this difficulty is given in Fig. 6. The right side of the impression is worn badly, while the left side is apparently the same as when first used. This condition was traceable to an uneven and worn base on the forging hammer. This allowed the die to rock back and forth as the forging was transferred from the breakdown side over to the finishing impression. This causes the center of force to be directed to one side of the center of the impression, and when the metal flows under the impact it will produce more abrasive action on this side of the die.

Occasionally form-cutting tools of high speed steel will repeatedly break in small sections while in use. The trouble may be due to improper design of the tool, insufficient or weak support of the tool holder, abusive grinding, overheating in hardening, insufficient removal of strains in tempering, or accidental jolts received as it engages the work. Poor design, flimsy support, and faulty tempering will usually result in a fracture into fairly good sized pieces, while overheated steel will crumble into smaller ones.

Blanking dies (Fig. 7) made from straight carbon tool steel will have a tendency to become slightly concave on the face of the die and convex on the back after regrinding operations, unless exactly the same amount of material is removed from the face as is ground off the back. Otherwise, due to the unbalance of forces in martensitic layers of unequal thickness, this will shorten the length of one side and bow the die. Many sheared punches can often be attributed to this condition in the die, rather than any defect in the punch.

Something might be said about the trouble due to a combination of grinding cracks and hardening cracks. Adam Steever has shown some good examples as late as the May issue of METAL PROGRESS.

High speed, high carbon-chromium, and other steels with an inherently hard, dense structure, and generally of the oil hardening type, are highly susceptible to checking by rash grinding. However, it must be remembered that every crack which occurs in grinding should not always be charged solely to the grinding operation. The strains and brittleness induced in a tool by overheating or insufficient drawing are merely exaggerated by the grinding operation. It is well known that such tools will crack with noticeably less severe conditions of grinding than tools properly heat treated. It will generally be found that when the grinding cracks are large, deep, and few in number, the principal factor involved is traceable to abusive heat treatment. When they are short, shallow, and numerous, the solution will be found in changing the grinding operation.

Figures 8 and 9 represent dies for cold forming knife handles from round stock and fastening them securely to the tang of stainless iron blades. One is an etched half section; it will be noted that the crack starting from the base of the

Fig. 7—Blanking Dies Warp Out of Flat Unless Ground Equally on Both Sides. Note edge view at left, against straightedge, snugly in contact at lower end

impression that forms the rim of the handle follows a curved path along the line of demarcation of hardness toward the corner at the base of the die. It was at first thought by the writer that this crack was due to insufficient hardness penetration in conjunction with too high an initial hardness. Various hardening and drawing temperatures, new steels, normalizing after each of several hobbing operations, were all tried without success, until an extra half inch was added

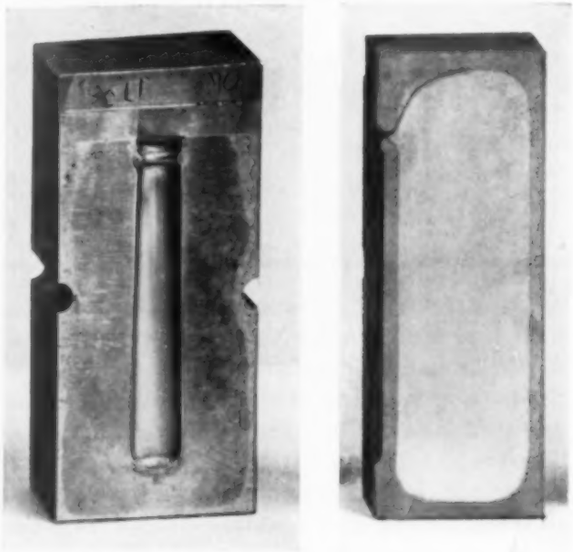


Fig. 8 and 9—Closed Die for Forming Knife Handles of Round Stock. Typical crack shown in sectioned block cured by cutting the impression in a more massive block, capable of resisting the wedge action of the bead of metal at the end of the blade

to the length of the die. This simple correction immediately tripled the former production. It seems that the shape of the rim section in this die compresses the metal into a hard, dense wedge, because it is blocked from movement and cannot emerge in a flash or fin. This wedge exerts more pressure against the side walls of the impression than the die is capable of withstanding. The extra half inch of backing must certainly provide enough support and rigidity to resist this action.

Frequently, recut dies break in hardening, and are frequently and wrongly blamed on pipe, even though such failures occur in striking dies that have already given satisfactory service records. These old dies are annealed, planed off, and engraved with another impression. The die then cracks on hardening or shortly after. Upon close observation, the familiar rings common to all fatigue failures will be seen; the trouble evidently started when the block was overstrained on a previous run. This finding will be further substantiated by deep etching with hot acid. Only the ordinary amount of segregation will be found in the immediate vicinity of the defect, and we know that pipe is always accompanied by an unusual amount of segregation; it therefore cannot be blamed for the failure.

Perhaps it would be well to close this article with a suggestion for overcoming a problem that occurs frequently in many plants with tools that require only one end, side, or part of the surface to be hardened. If such pieces are quenched by immersing only those parts which are desired to become hard, warps and possibly cracks will occur from unbalanced strains between the hardened and unhardened portions.

Partial Hardening

The method of procedure recommended is as follows: The tool is heated with the usual precautions in one furnace until it is above the Ac_3 critical point. When thoroughly heated through at the correct temperature, it is withdrawn from the furnace, and the parts that are desired to remain *soft* are cooled to a temperature below the Ar_3 critical point by wet asbestos pads or water spray fixtures. The remaining uncooled parts are still above the lower critical point, and therefore unhardened. The tool is then quickly placed in another furnace which is maintained some 20 or 30° above the Ar_3 point and the tool is then allowed to become equalized in temperature. This has the effect of a very high draw on the regions that have previously been cooled, thus removing any hardness they acquired. The parts desired to be hard, however, have always been above the critical temperature; due to the fact that the transformation on heating (Ac_3) is considerably above the transformation in cooling (Ar_3) the parts to be soft have not been reheated above the Ac_3 range, so they will not reharden. Now the tool is *rapidly* quenched all over. Only those sections which had not been cooled by the previous treatment will come out hard, and yet the least possible temperature gradient will exist between the hard and soft portions of the tool while being quenched. Incidentally, this method will also hold shrinkage and change of hole size at a minimum with blanking dies, which require only a shallow depth of hardness.

Present limitations of nickel-chromium resistors — say 2100° F. — are surpassed with new alloy which is strong and ductile while hot, and can be swaged from ¼-in. rod to ⅛-in. wire. It has long life at 2300° F.

A New Resistor Alloy

Chromium-Aluminum-Iron

AT THE PRESENT TIME the standard alloy for heating elements in electric furnaces for the higher temperatures is the conventional 80% nickel, 20% chromium alloy, which was developed by the pioneer of heat resisting alloys, A. L. Marsh, and patented by him in 1906. It is known on the American market as the "Chromel A" of the Hoskins Mfg. Co. and the "Nichrome V" of the Driver-Harris Co. Nickel-chromium alloys of this family have a high electrical resistance and withstand oxidizing atmospheres at temperatures up to approximately 2000° F. (1100° C.).

While the nickel-chromium resistors are very widely used, there are applications of electric heating for which higher temperatures are desired than can be reached with these alloys. As a consequence numerous attempts have been made to develop metallic resistors for use at higher temperatures, and several alloys have been marketed to fill this need.

One of these is "Megapyr," an alloy of iron, chromium, and aluminum made in Germany; another is "Kanthal," an alloy of iron, chromium, aluminum, and cobalt made in Sweden; two others are "Alcress," and "Ohmax," alloys of iron, chromium and aluminum, made in this country.

By S. L. Hoyt
Director, Metallurgical Research
A. O. Smith Corp., Milwaukee

The latest of the heat resisting alloys is known as "Smith Alloy No. 10." It was developed in the metallurgical laboratories of the A. O. Smith Corp., and is the subject of Patent No. 1,995,923 granted to S. L. Hoyt and R. S. Archer. The preferred composition is about 37.5% chromium and 7.5% aluminum with minor amounts of other elements, in addition to iron. In other words, it is essentially a ferrous alloy of chromium and aluminum. The composition used for electrical resistors gives a desirable combination of extraordinary stability at high temperatures, high fusion temperature, and good working properties at elevated temperatures.

Quantities of this alloy have been made in 30-lb. or 200-lb. induction furnaces in the metallurgical laboratory. The metal is cast into 20-lb. or 50-lb. ingots, which are then rolled at a wire mill to ¼-in. rod. This rod is then returned to the metallurgical laboratory where it is hot swaged to ⅛ in. diameter or to some intermediate size. This rod or wire is then formed hot into coils or other shape for use as heating elements. Aside from the necessity of doing this hot the forming operation involves no serious difficulties, for the wire is strong and tough at elevated temperatures.

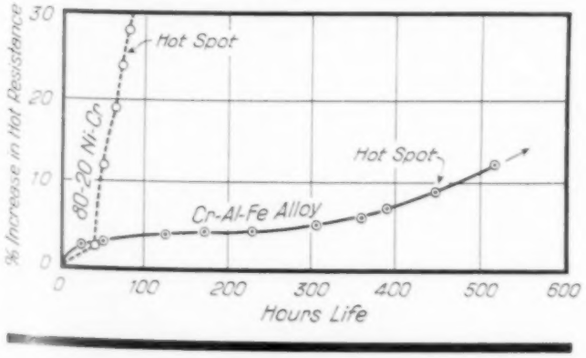
Before passing to the performance of furnaces wound with the new element, we shall first consider the results of life tests. A good indication of its possibilities may be had by comparing it with the 80% nickel, 20% chromium alloy.

The method of life testing wires for heating

elements is specified in "Standard Accelerated Life Test for Metallic Materials for Electric Heating" (B75-33 of the American Society for Testing Materials). This is essentially the method of Bash and Harsch, according to which a 21-gage wire (diameter 0.028 in.) is put through heating cycles of two minutes duration at 1950° F. until the wire fails. The criterion of excellence is the time or life to a 10% increase in resistance. We have maintained the essential features of this test but have limited the tests to ⅛-in. wires, and have added a control utilizing a photo-electric cell as a means of maintaining a constant wire temperature. This test gives consistent and reproducible results.

A general idea of the improvement over the nickel-chromium alloy which we found at an early date can be obtained from the curve herewith, which gives the results on ⅛-in. wires at 2300° F. with a time cycle of 3¾ min. on and off. While neither wire was "selected," the nickel-chromium alloy was of good commercial quality so that this test indicates a marked improvement in stability of the "No. 10 Alloy" at 2300° F. This is shown by the increase in life from about 40 hr. for the nickel-chromium alloy to 500 hr. for the new chromium-aluminum-iron alloy. The life of the latter at 2300° F. is too long for routine testing, and we have adopted a black body temperature of 2600° F., at which temperature the life of our ⅛-in. wires is on the order of 100 hr. This temperature is above the melting point of the nickel-chromium alloy. The ⅛-in. wires have run 10 hr. at 2650° F. with an increase in resistance of 7%. These temperatures are black body temperatures without correction for emissivity, and it is interesting to note that when the emissivity correction is applied, the actual temperature of the wire when being tested at 2650° F. is found to be in excess of the melting point of pure iron. The emissivity used here is 0.5, as recommended by the Bureau of Standards.

Life Test of 80-20 Ni-Cr Alloy and "Smith Alloy No. 10"; Both ⅛-in Wires at 2300° F.



A number of furnaces wound with the new alloy have already been made and tried out in a practical way. In addition to this experience gained in our own work we have been fortunate in having the cooperation of members of the staff of Hevi Duty Electric Co. of Milwaukee, who have carried on an extended commercial development. This experience has confirmed the results of the life test and, indeed, it has shown clearly that "Alloy No. 10" is capable of giving entirely satisfactory service for furnaces operating well above 2000° F. These furnaces have run many hundreds of hours, and in some instances many thousands of hours, at temperatures ranging from 2150 to 2300° F. (1175 to 1260° C.). Temperatures of 2400° F. (1315° C.) and above can be easily obtained although some loss of life will necessarily result. On one occasion one of our furnaces ran away, due to the sticking of a clapper control, and heated above 2500° F. (1375° C.) which was the limit of our recording pyrometer. The damage done was inconsequential and the furnace ran for an additional 7,000 hr.

The electrical resistance of "Smith Alloy No. 10" is of the order of 1000 ohms per circular mil foot, or 170 microhms per centimeter cube, while the nickel-chromium alloy has a resistance of 660 ohms per circular mil foot or 110 microhms per centimeter cube. At high temperatures the resistance passes through a maximum at about 1700° F. and then decreases to a value about 5 to 7% greater than the resistance at room temperature. This high resistance means that higher voltages or larger heating elements or both can be used in furnace design.

The melting point is known to be very high. This is indicated by burning off a wire with an electric current and comparing the melting point with that of the nickel-chromium alloy. A more accurate determination of the melting point can be obtained by heating a sample in an induction furnace under a high vacuum and finding the temperature at which incipient fusion begins. This temperature of incipient fusion is of more significance to the operation of the heating element than the final melting point, and has been used in our determinations. By setting up the sample to secure black body radiation the optical pyrometer gives the true temperature to which it is subjected, and by repeating the test at increasing temperatures it is possible to find

the temperature at which fusion begins. By this means L. Reeve and M. A. Scheil determined the temperature where melting begins for a number of heat resisting alloys and soft steel. The low carbon steel was found to fuse at 2775° F. (1525° C.) which indicated that the temperature measurements were reasonably correct. (Melting point of pure iron is given as 2786° F. in National Metals Handbook.) The temperature of incipient fusion of a sample of "Alloy No. 10" with about 37.5% Cr and 7.5% Al was returned to 2830° F. (1555° C.) by this method, or well above the melting point of pure iron. A high melting point is a valuable property of a heating element, for it means that the element can be operated with higher current densities without fusing the center.

The density of "Alloy No. 10" is 6.9 grams per cubic centimeter, so that the volume is 22% greater than the volume of the same weight of the standard nickel-chromium resistor.

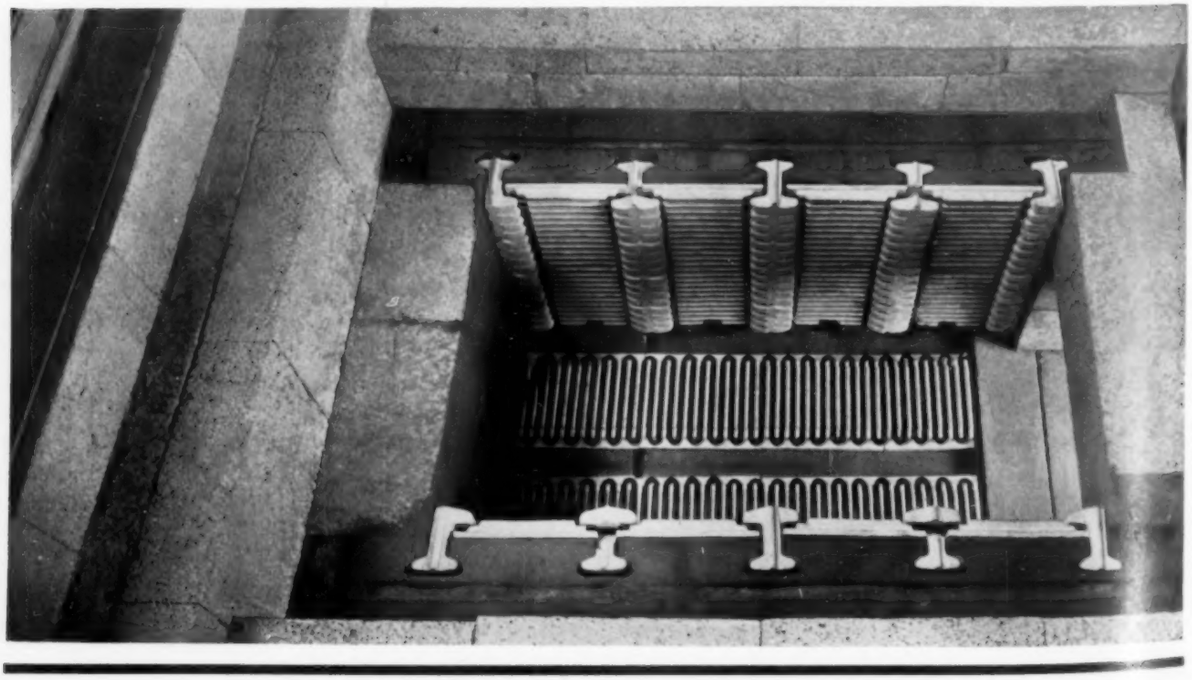
In the design and construction of furnaces for operation at the high temperatures which can be attained with the new heating element, due regard must be paid to the necessity for providing the right kind of refractories, and for using suitable supports which allow for the thermal expansion, growth, and sagging of the resistance element. These are new problems in furnace operating temperatures. The accompanying photograph illustrates how the elements are mounted in a moderate-sized hearth furnace.

It is now industrial history that the electric furnace has acquired an important field for itself on account of the special advantages of this method of heating. At temperatures above 2000° F. the relative cost of electric energy and other forms of fuel energy becomes more favorable to the former, while the metallic resistor provides all the features of simplicity of equipment, ease of control and maintenance of temperature and furnace atmosphere, cleanliness, and simplicity of operation which have made this furnace so popular in the past. We confidently believe that the new alloy will provide all of these advantages for high temperature applications. While still in its infant stage, it has already opened up new fields for electric heat.

An important, even controlling, feature of the commercial use of a new product is the uniformity of performance that can be relied upon. A great amount of attention has been paid to this, for it was early realized that the manufacture of high aluminum alloys is bound to give variable results unless the whole process is amenable to and actually is under strict control.

A commercial process of making "Smith Alloy No. 10" has been developed through a period of very intensive research in which many heats were made and tested for uniformity by chemical analysis, by rolling and swaging, in life test and in furnaces. It is now possible to make heating elements which will consistently have suitable working properties and high temperature stability of the order described above.

View (Roof Removed) Into Interior of 20-Kw. Box Furnace, Showing Heating Element and Insulation Construction. Floor of furnace is missing. Courtesy Hevi Duty Electric Co.



In the last of a series of articles, Dr. Merica (the man who first explained the mechanism whereby duralumin becomes hard) describes heat resistant and magnetic alloys that owe their origin to the same action, and gives some ideas as to the atomic movements involved in precipitation hardening

Some Alloys Having Great Thermal and Magnetic Stability

THIS is the last of four articles, adapted from addresses recently given on the general subject of precipitation hardening. In the first, published in January in METAL PROGRESS, three classes of microstructural changes were described, each associated with hardening phenomena. The most important, sometimes called the duralumin type of hardening, is caused when a solid solution, supersaturated with a constituent by rapid cooling, gradually precipitates that constituent at room temperature or during moderate tempering. A second, which may be called the beta bronze type of hardening, has some features in common with martensitic hardening, for the softer beta solid solution transforms into a harder eutectoid aggregate. Lastly is an important class of reactions in precious metals, where one solid solution stable at higher temperature gradually changes into another solid solution having a different atomic lattice at lower temperature.

In the second article (METAL PROGRESS for March) were discussed three important nonferrous metals — namely aluminum, copper, and nickel — and their hardening either as cast or wrought by one or the other of these mechanisms. In the third article, last month, it was pointed out that the age hardening of steel probably was responsible for such unwanted actions as the gradual hardening of deep drawing sheet in storage, the local embrittlement of flanged boiler plate, temper brittleness of certain alloy steels, and the hardness of weld metal. Duralumin type of hardening is also possible in the copper steels, a feature which probably will be of increasing importance, whether for good or ill.

By Paul D. Merica
Assistant to President
International Nickel Co.

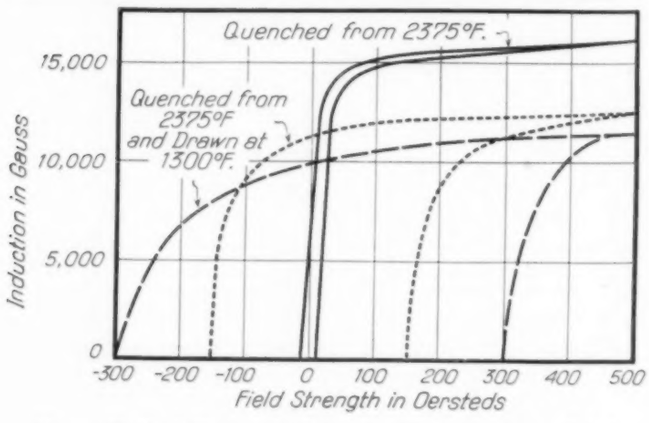
Thermally Stable Alloys

Now my remarks so far have emphasized particularly the enhanced physical properties of hardenable alloys when used at ordinary temperatures — and indeed that enhancement is the principal asset which all age hardening alloys have in common. But it is not the only one and I should like to describe briefly two alloy systems which most admirably exhibit a useful variation of this principal theme.

First it should be noted that the aging temperature ranges of alloys are loosely related to their normal annealing temperatures — namely, those temperatures at which, after cold working, the alloys soften and recrystallize. You will understand that when I wrote "loosely," I wished to indicate that there are some pretty striking exceptions to this relation. However, as we pass from the alloys of metals of lower to those of higher melting point, the softening temperature ranges (and in general also the age hardening temperature ranges) increase. For instance, the fusible

lead-base alloys age at normal temperatures; copper-base alloys are tempered normally around 500° F., copper-nickel alloys require tempering temperatures around 900° F. Alloys of high melting point metals, such as iron, nickel, and cobalt, have to be aged at temperatures as high as 1100° F.

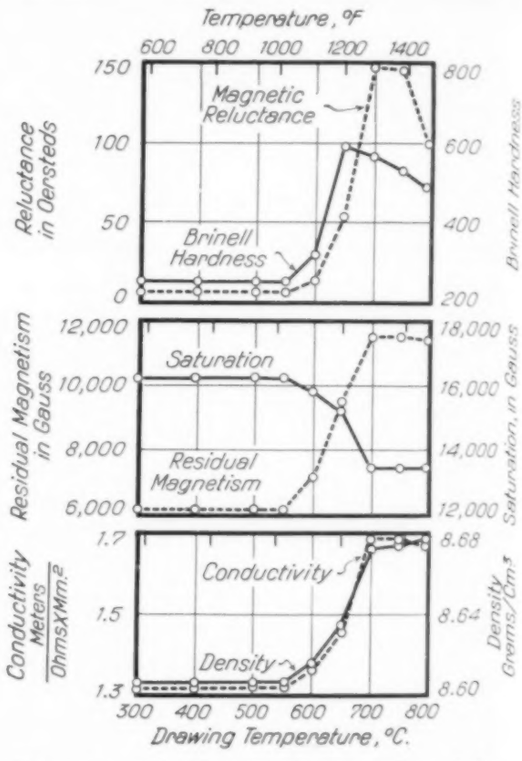
In some of these alloys the hardening precipitates formed at these higher temperatures seem to be extraordinarily sluggish in coalescing, and as a consequence these alloys retain a very substantial measure of hardness and strength at these temperatures — even after prolonged exposure to them. In other words, they have a good resistance to "creep."



Upper Half of Hysteresis Loop for Iron-Tungsten-Cobalt (67-18-15) After Quenching From 2375° F. It is then soft and easily changes with the magnetizing force. However, if it is tempered at 1300° F., the coercive forces are very great, and the material then makes a good permanent magnet

This characteristic of mechanical and thermal stability at high temperatures is a principal asset of the "Konal" series of alloys developed by the Westinghouse research staff. These are quaternary alloys containing about 2% of titanium, the hardening agent, and consisting otherwise principally of nickel, about 70%, together with about 17% of cobalt and 6% of iron. After aging at 1100 to 1300° F., some of these alloys develop elastic limits as high as 60,000 psi., when determined on tests made at 1100° F. — truly remarkable figures for these high temperatures. Konal is used at the present time largely for vacuum tube filaments.

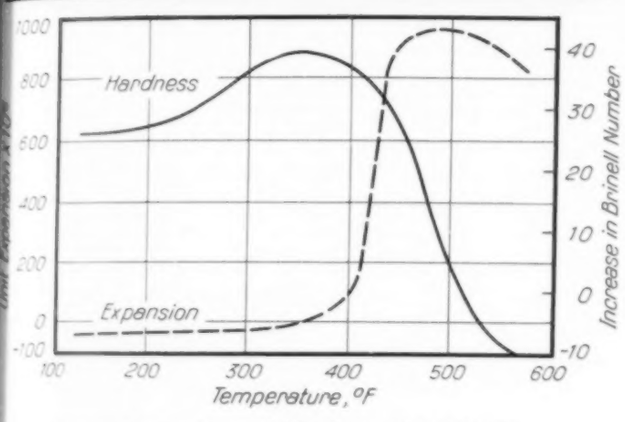
Another most interesting alloy, that of tungsten (about 30%), cobalt (about 25%) and iron (about 35%), has been developed and described by Sykes and Jeffries in METAL PROGRESS for February, 1933. It hardens during tempering at about 1100° F. by the precipitation of a tungsten-iron compound and becomes quite hard — around C-60 Rockwell — but because of the high temperature at which this precipitate is formed and its sluggishness and stability at these temperatures, the alloy has to a high degree the quality of red hardness. It is therefore being developed for cutting tools. Here is a high speed cutting alloy in which carbon plays no part, and is indeed practically absent! The red hardness is due to quite different structural features than in its competitor, high speed steel — namely, the presence of disperse precipitate of iron-tungsten.



Magnetic and Mechanical Properties of Iron-Tungsten-Cobalt (67-18-15), Quenched from 2375° F. and Tempered Variously (Koester, 1933). It is evident that a precipitation hardening affects the magnetic and the electrical properties proportionally

Although I have cited what are at the moment extreme examples of the contribution of age hardening to the high temperature properties of metals, they only illustrate, however strikingly, the fairly general truth that fine disperse precipitates have, not only at ordinary temperatures but within the entire temperature range of their struc-

tural stability, an unusual power of stabilizing their host lattice, of resisting slip in it, and consequently of maintaining a high degree of hardness and of strength. This asset is likely to prove an increasingly valuable one, since it is precisely within the temperature range of stability of the age hardening alloys of such metals as iron, copper and nickel that improved mechanical properties are now urgently sought for many engineering applications, such as equipment in connection with the use of superheated steam.



Linear Expansion and Hardness of 4.30% Copper-Aluminum Alloy After 8-Hr. Stay at Different Temperatures (After Portevin & Chevenard)

Our discussion so far has been concerned primarily with mechanical hardness and its relation to precipitation aging. There is another set of important physical properties which may be profoundly affected by properly designed phasial precipitation and those are the magnetic properties of metals.

"Magnetic hardness," if I may use the term, may be induced by aging in certain alloy systems in a manner somewhat analogous to that of mechanical age hardening. This possibility is naturally limited to ferromagnetic materials and has been developed in connection with certain of the magnetic alloys of iron, by various men in the Western Electric Co.'s organization, as well as by Koester and others abroad.

Age Hardening and Magnets

It would appear that if the homogeneity of internal grain structure or lattice structure is disturbed in any magnetic material, the response to applied magnetic fields of the atomic magnets of which it is composed becomes less sensitive and complete. The material becomes "magnetically hard," as we say, and this behavior is reflected in an increased coercive force. It is the magnetically hard materials — those with high values of coercive force — of which permanent magnets are made.

Now this homogeneity of internal structure may be upset in many ways; for example, we may do it by cold working or (as in the case of martensitic magnet steels) by the lattice distortion in alpha iron, imposed by the presence of atomically dispersed carbon. It is not surprising that the distortion produced by other varieties of precipitates in fine disperse form should have the same effect.

An iron alloy containing 18% of tungsten and 15% of cobalt is, when quenched from 2375° F., entirely in the alpha or magnetic condition and exhibits magnetic properties characteristic of alpha iron — high induction and fairly low coercive force and hysteresis. It is, however, supersaturated with respect to the compounds CoW and Fe_2W_2, and upon tempering at 1300° F., these compounds are precipitated in fine disperse form and the coercive force of the material increases very substantially from a value of perhaps 10 to about 300 gilberts per cm. The relationship of these properties with hardness and specific weight is shown in the accompanying diagrams on page 42.

There are a number of magnetic alloys which are susceptible of hardening in a similar manner, including the aluminum-nickel-iron alloys, described fairly recently by Mishima. Some of them appear to have magnetic properties in many respects superior to those of the simple magnet steels and may prove to be of definite practical value for the construction of permanent magnets. Although they are generally likely to be more expensive because of the presence of alloying materials, they have as a class certain very definite advantages as compared to steels. First, their fabrication by machining is easier, since they may be quenched soft, machined, and thereafter magnetically hardened by a tempering treatment, which involves but negligible distortion. Second, their magnetic properties are stabilized by tempering at a relatively high temperature — about 1200° F. — and are not subject to slow alteration by aging, as is often the case with the common magnet steels.

It would seem that for many special purposes the use of such alloys would be economically justified in substitution for cheaper materials,

and as a matter of fact, active consideration is being given these alloys today in several of our principal magnetic laboratories.

A Little Theory

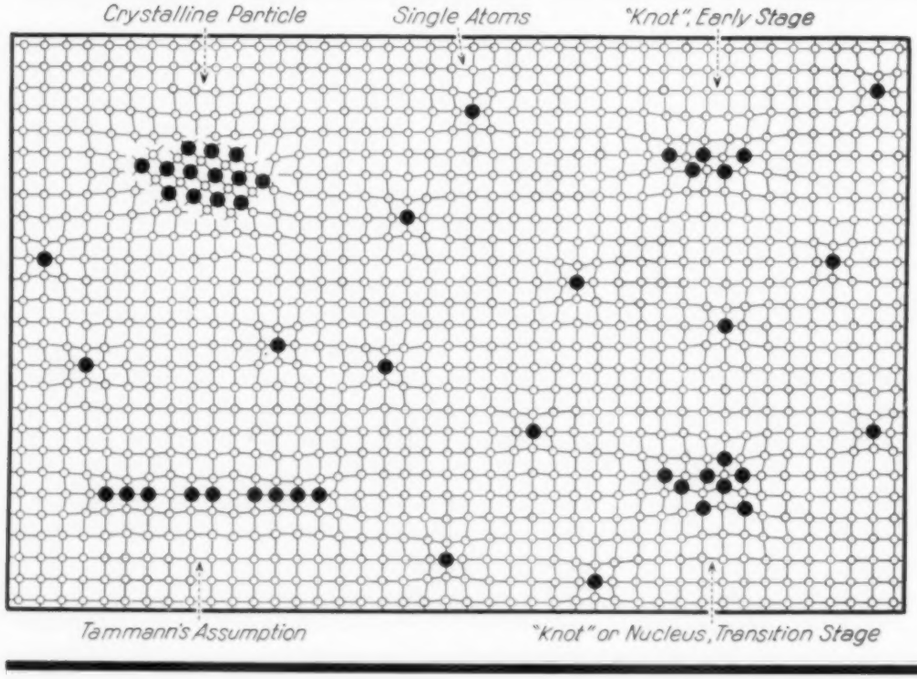
Well, I am now at that place in my dissertation where I am about to use those encouraging and heartening words — *in conclusion!* And I am there, I am afraid, in spite of the fact that I have left many interesting aspects of the subject untold and many questions unasked.

I should, for example, like to write more on the subject of the variable hardening response of age hardening systems — why some "hardeners" do a good job of hardening and others a pretty poor one. Copper age hardens aluminum very nicely, but silicon performs only mildly, although its solubility relations seem quite well adapted to precipitation hardening response. A most interesting case is that of the silver-copper system, discussed in the first article (January); in it the temperature-solubility relations at both the copper and the silver ends are apparently quite similar, and well suited to permit age hardening. Yet although the copper-silver alloys harden well enough, the silver-copper alloys show but a faint response to appropriate heat treatment. Evidently we must know much more about the crystallographic relations of hardening precipitates and their host lattices before we can understand thoroughly the behavior of such alloys as these.

And you may enjoy speculating also on the interesting fact that in some alloy systems, such as that of 50% aluminum-silver, age hardening is accompanied by an actual decrease of tensile strength!

Unfortunately, the answers to these questions and many others like them are not yet available, although there has been much interesting and suggestive speculation about them. I do want to put in just one more word, however, on the theory of precipitation hardening, for I have referred to it as if it corresponded wholly to phase segregation as we usually observe it in alloys — under the microscope, for example.

The precipitates that give rise to age hardening are not, however, actually as simple as I have presented them and in fact there are those who dispute the very existence of precipitates in some age hardened alloys — in duralumin in particular — and who say that the term "precipitation hardening" is a misnomer unless the precipitated substance can be seen under the microscope. However it must be remembered that these "precipitates," if that is what they are, are generally so fine in dispersion as to be invisible under the microscope. We frequently see but little difference in microstructure (even in tone and response to etching) between the homogeneous structure of such an alloy when freshly quenched and soft, and that after aging, when it is fully



Supposed Atomic Arrangements in "Lattice Knots" and in Crystalline Particles. Single atoms distort slightly the surrounding lattice. "Knots" in their early stages are small, and atom planes are continuous but considerably distorted. In intermediate or transition stages "knots" are larger and some disregistry of atom planes appears. Crystalline particles exhibit practically complete atom-plane disregistry except perhaps along one set of planes. Tammann assumes that stranger atoms tend to line up along glide planes of host

hard. That, of course, need not surprise us much, since quite large crystals of such precipitates, containing thousands of atoms, could still be much too small to be resolved by our very best microscopes.

When we investigate age hardening by more delicate and revelatory methods, such as the X-ray or dilatometer, we indeed find in some cases that all of the evidence indicates the formation during age hardening of a presumably crystalline precipitate, in entire accord with the simple theory I have presented. These cases may perhaps be labeled "normal" or "simple" age hardening systems.

On the other hand, in some cases, notably in that of duralumin, such methods fail to reveal any evidence of the formation of precipitate even after full hardening at room temperature. Hardening at these temperatures appears to be quite complete before those changes occur in lattice constant and in specific volume, that we know are associated with the precipitation of the hardening constituent, in this case $CuAl_2$. (See, for example, the diagram on page 43.) Consequently, it has been urged by some, both here and abroad, that hardening in this and similar cases is due, not to actual precipitation, but to some other lattice rearrangement involving a considerable amount of lattice distortion.

"Abnormal" Aging

Now, although I shall say at once that I do not believe there is much fundamental difference between this group of alloys and the "simple age hardening systems," they may, for the sake of convenience, be thought of as "abnormal age hardening systems." This group includes, for example, the aluminum-copper-nickel alloys described in the March article.

No very clear picture has been put forward, by the critics of the simple precipitation theory, of the exact progress of internal affairs during the aging of these "abnormal" alloys. Indeed our instruments of investigation today hardly permit us to know much of what is actually happening. It has been suggested by Tammann that the copper atoms line up during room temperature aging along the glide planes of the aluminum lattice but still on its lattice points, and there seems to be some X-ray evidence favoring this view.

However, the important thing to bear in mind is that, as far as we know, no gross change either in lattice type or in lattice spacing takes place in such cases. I feel, therefore, that we are justified for the present in taking the simple view that, whatever be the precise nature of this atomic process which occurs during the room temperature aging of duralumin, it may be regarded as of a nature directly preparatory to the formation of the crystalline particle which precipitates and hardens. In this sense it probably involves some diffusion of the hardening atoms toward nucleus centers which may later become crystalline particles. One can conceive, therefore, of hardening particles or "lattice knots," which represent a segregation of the hardening atoms previously dispersed throughout the solid solution, but which are still, after segregation, on the lattice of the host metal. Because of the substantial distortion of this lattice by the crowding in of the stranger atoms, these embryo segregates or "knots" are in position to interfere with slip just as well as if they were crystalline and of a different lattice type. These ideas are presented, but poorly, I am afraid, in a two-dimensional sketch taken from my 1932 lecture before the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers.

From the practical standpoint of discovering age hardening alloy systems and of designing suitable hardening heat treatments for them, it fortunately makes little difference whether we think of the hardening as being due to actual precipitation of a new phase, or whether as merely incident to the prior diffusion and lattice distortion which precede and prepare for precipitation. The response of such systems to manipulation, qualitatively at least, accords quite nicely with the simpler view and until our knowledge of atomic movements in solids is considerably advanced, we may perhaps profitably thus leave this most perplexing but important theoretical question.

And now I have really finished, and if in this brief review of the subject I have been able to impress you that in the modern technique of age hardening we have a tool that can aid us most powerfully in the development of new and useful alloys; if I have convinced you that precipitation hardening is not a rare but practically a universal phenomenon which can more frequently than not be put to useful work; if you have gotten the idea from the probably undue amount of speculation which I have permitted myself, that there is a lot still to be learned about age hardening, then perhaps I haven't been too delinquent in my job. For those are the simple facts about age hardening that I believe to be interesting and useful.

Chapter Chairmen

Raymond

E. G. Brick

Heberger

W. T. Morgan

E. F. Ross

Bachrach

G. W. Quick

R. P. Koehring

W. D. Kellogg

A. S. M. 1934-1935

MEN who are elected chairmen of the local chapters of the American Society for Metals are naturally those whose capabilities have already been proven in the business and technical world. It is therefore fitting that METAL PROGRESS devote some space to the biographical high-lights in the lives of chapter chairmen. The following six sketches initiate a series which, it is hoped, can be continued in subsequent issues.

E. G. Brick

E. G. BRICK, chairman of the Detroit Chapter, 1934-35, was born at Romulus, Mich., close to the beginning of the 20th century, but followed his family to Detroit at the age of two years. With 16 long, hard (Michigan) winters behind him, he ambitiously entered the business world. After learning all that he cared to know about the banking business in one short month, he promptly and properly deserted that lucrative though now discredited field to serve nearly four years in a steel rolling mill (American Car & Foundry Co.) in capacities ranging from shipping clerk to service manager.

The last four months of the War were spent in the tender arms of the Navy, the next stop being Ann Arbor, with a net result of one degree (B. S. in Chemical Engineering) obtained in 1924. Then came four years of catering to the vagaries of gray iron cupolas, aluminum melting pots, and brass melting furnaces in the foundries of the Cadillac Motor Car Co. After one year spent selling power plant equipment, he returned to Cadillac as assistant metallurgist and so remained until transferring in December, 1933, to his present connection with the Alloy Division, Youngstown Steel & Tube Co.

Mr. Brick has been a member of the A.S.M. since 1924, has served on the Detroit Chapter Executive Committee during 1930 and '31, as vice-chairman in '32, and as secretary in '33. He was also a member of one of the sub-committees of the Recommended Practice Committee.

W. T. Morgan

JUST "Bill" to friends, W. Trefor Morgan was born in Wales and educated at Swansea Technical College and Sheffield University. He came to the United States eight years ago and owes his first job to having been taken to the New York Chapter meeting almost on landing! Hence his devotion and enthusiasm for the Society.

For the past six years Mr. Morgan has been chief metallurgist of Taylor Instrument Companies, Rochester, N. Y. He is a member of the Pyrometer Sub-Committee of the Recommended Practice Committee and serves on the Membership Committee of the Institute of Metals Division, A.I.M.E. Five years on the Executive Committee of the Rochester Chapter were followed by the chairmanship.

E. F. Ross

ERLE FRANKLIN ROSS brags that he attended the convention in Philadelphia in 1920 when the A.S.S.T. was established and has attended every convention since that time. He even went to the Second Western Metal Congress in San Francisco, and that is a long way from Cleveland, where he headed the chapter for the season just completed, and took great pleasure in ringing the "President's Bell" now in the possession of that chapter.

Mr. Ross has a B.S. in Electrical Engineering from Purdue and has been with Penton Publishing Co. since 1919. He is at present associate editor of *Steel*, specializing on technical subjects.

When the A.S.S.T. transferred its headquarters from Chicago to Cleveland early in 1921, he became editor of the *Transactions* until 1922, when a full-time editor was appointed in the person of Ray Bayless. He was also on the Publication Committee of the Society from '28 to '30.

W. D. Kellogg

BILL KELLOGG ("Cornflakes" to friends) decided, after graduation from Georgia Tech in 1911, to test out the old adage that a rolling stone gathers no moss but rounds off the corners. After exposure to an apprenticeship course with Westinghouse and a return visit to Georgia Tech to teach experimental engineering, he spent several years in Baltimore, Washington, and Milwaukee convincing factories that electric motor drive was better than steam, and installing lighting plants.

The next five years were spent in western Canada operating a storage battery and gasoline engine manufacturing plant, but feeling that the severe winters were slowly freezing him, and finding a few corners not yet sufficiently rounded, he moved to Norfolk, Va. For the next seven years he thawed out while building special machinery and aviation armament equipment.

His next move was to Amsterdam, N. Y., where he has charge of mechanical research and patent prosecution for Mohawk Carpet Mills. He

found a congenial group of research workers in nearby Schenectady, whose A.S.M. chapter he chairmanned in 1934-35.

G. W. Quick

WITH the exception of one year spent in the electrical business, G. Willard Quick has been with the U. S. Bureau of Standards for eighteen years. He is at present associate metallurgist and in recent years has engaged in considerable research work on propeller blades and rail steels.

He was graduated from the University of Richmond and received his metallurgical training under Dr. William Campbell at Columbia University.

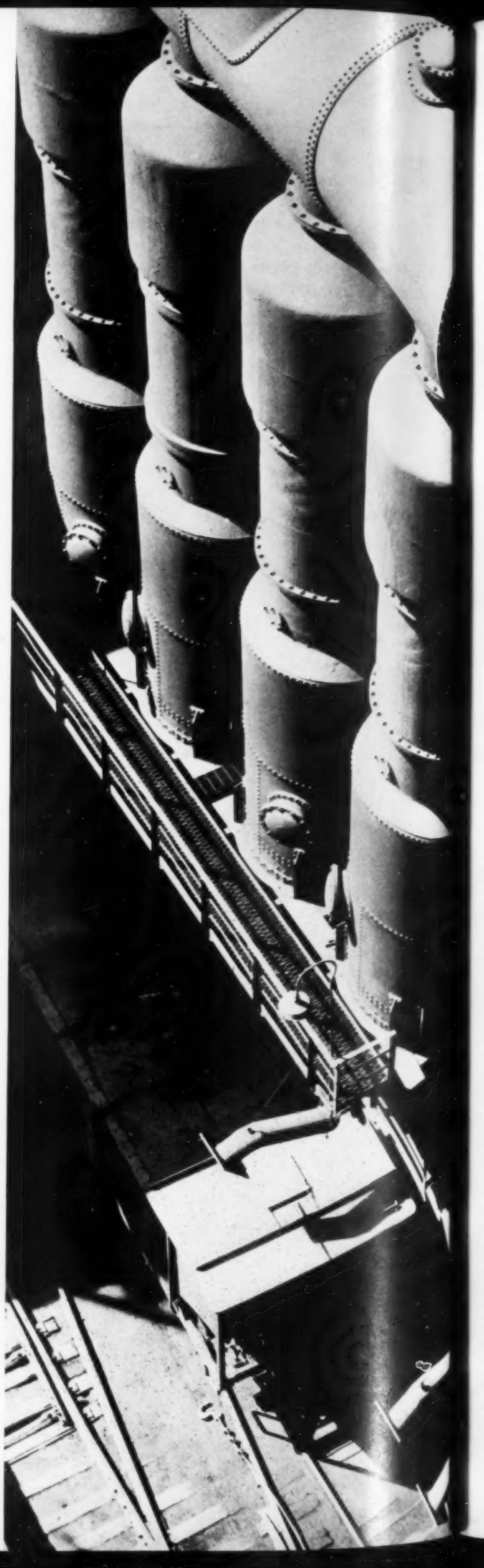
His outside activities are numerous (most important, of course, being his long service as secretary-treasurer, vice-chairman, and chairman for the Washington Chapter, A.S.M.). As chairman of an A.S.T.M. sub-committee, he has supervised atmosphere exposure tests on screen wire cloth in as widely varied spots as Pittsburgh, Portsmouth, Va., Cristobal, C. Z., and Washington. He has been technical secretary of the Metals Committee, Federal Specifications Board, since 1926.

R. P. Koehring

DAYTON Chapter's chairman is a man whose name has for many years been associated with "Durex," General Motors' porous graphited bearing material molded from powdered metals.

When the General Motors Research Laboratories were organized in Dayton in 1920, Roland P. Koehring secured a position as an assistant in the Chemical and Metallurgical Research Section, which pioneered the raw material. In 1925 the Laboratories were moved to Detroit and the Moraine Products Co. was organized for commercial production of Durex. Mr. Koehring has been the Moraine Co.'s metallurgist ever since, and is still digging deep into the problems and possibilities of molded powdered metals. It is a new branch of the metallurgical art, with enormous possibilities.

He is a member of the A.I.M.E. and American Chemical Society.



Top-Man's View of Dust Catchers in Cleaning System for Blast Furnace Gas, River Rouge Plant. Courtesy of Ford Motor Co.

Letters and Comment

Copper Steels

CLEVELAND, *Ohio* — "As near as I could discover, someone about 75 years ago, being unable to explain the cause of failure in certain steel for any other reason, discovered that it contained a little copper, and it was new to him that any steel ever contained any copper because it was not ordinarily looked for or determined. Consequently specifications appeared limiting the amount to 0.05% without any particular rhyme or reason, and as is usual this was repeated many times in other specifications for a period of years."

The above is from the Joseph W. Richards Memorial Lecture, given before the 1932 meeting of the American Electrochemical Society by the late John A. Mathews. His subject was "The Electric Furnace and the Alloy Age." He might have gone on and pointed out that the best Swedish wrought iron, from which leading German, English and American tool steels had been made since the beginning, contained from traces up to 0.20% copper. Also that the important ore deposits near Cornwall, Pa., long the source of material for the mills in Scranton-Lebanon region, produced millions of tons of excellent steel containing from a few points up to 0.50% (and even 0.60%) copper. Likewise that 0.25% copper was recognized as a powerful rust resistor in steel sheet and plate, and that four times as much had been successfully employed in oil country tubular goods.

Nevertheless, as late as 1923 (as the Editor can testify from his personal experience) the prejudice against copper in steel was so great that the most progressive factors in the copper industry rejected a suggestion that their metal be studied as an alloying element. This decision was reversed only a couple of years ago and an investigation financed by the Copper and Brass Research Association — to good effect, as shown by the summary of present knowledge about it given by C. H. Lorig in April METAL PROGRESS.

The commercial copper-nickel-molybdenum steel described by Mr. Miller on page 28 is only one of a long list of copper steels which may be expected in the future. The importance of this family of alloys can hardly be prophesied, for it is not merely a new alloy steel, hardened by carbide, but one which improves the alloy primarily by strengthening the ferrite. Furthermore, it exhibits to a notable degree the phenomenon of precipitation hardening, whereby the air-cooled material is strengthened throughout by annealing at moderate temperatures. While present applications of high strength sheet do not anticipate the use of such a property, it has enormous possibilities, for hardening by such means not only avoids the well-known difficulties associated with drastic quenching, but is an application to iron of those principles that underlie the successful hardening of aluminum and the other "soft" metals.

ERNEST E. THUM

Micro Testing Machines for the Study of Welds

PARIS, *France* — In a letter to METAL PROGRESS, November, 1933, I attempted a definition of "weldability" as the product of the two qualities of the joint — "compactness" and "homogeneity." It was pointed out that to arrive at a numerical evaluation of homogeneity, it would be necessary to cut the weld into very small test pieces and study the metal bit by bit.

Such a micro-mechanical analysis of a weld seems to be the only way a true idea of its character may be had. Metallography and hardness testing (using a very small indenter) provide extremely useful information, but do not reveal the mechanical properties, such as ductility and resistance to tension or shear, or the resistance to corrosion. The usual tests on a complete joint, or a standard test piece cut therefrom, measure only the minimum characteristics of a heterogeneous whole, and while useful in fixing design stresses, are disappointing when one is attempting to improve the characteristics of a welded structure.

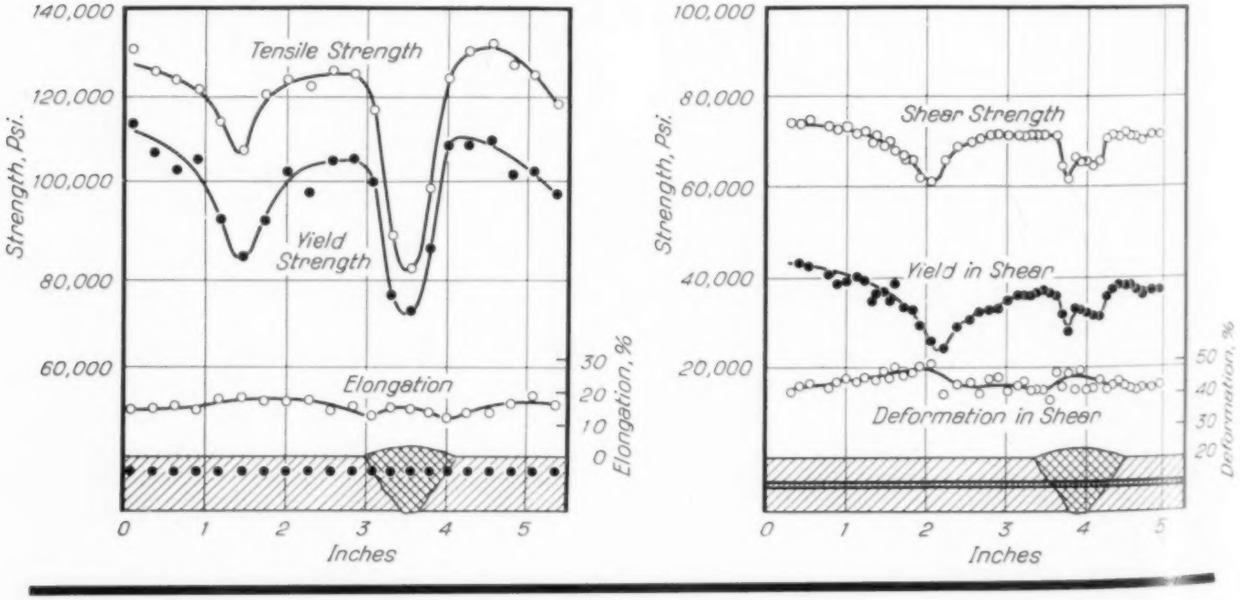
Equipment for making these small-scale tests has been devised by Pierre Chevenard and constructed in the laboratory of d'Imphy steel works. It utilizes tensile test pieces 1.5-mm. diameter and 7-mm. gage length (0.059x0.276 in.) or shear or bend test pieces 1.5-mm. diameter.

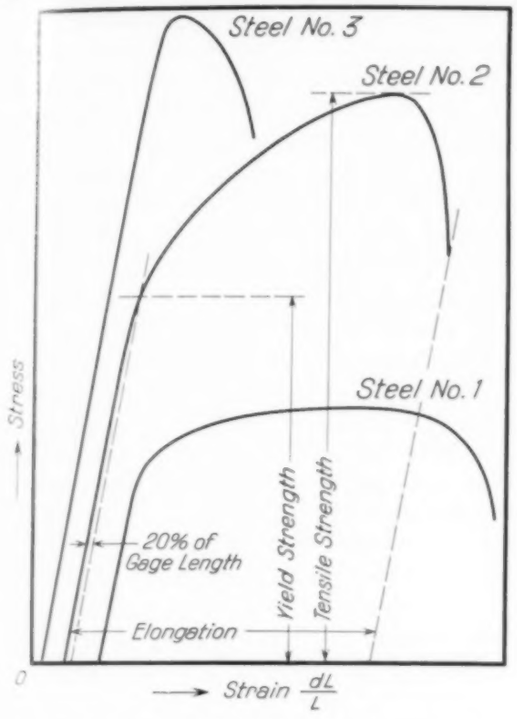
For making a tensile test, the specimen is screwed into spherical holders, one of which fits into a recess at one end of a lever and the other into an identical recess in the end of a leaf spring. This spring is calibrated and makes a reliable dynamometer free from friction. The lever is then moved away from the leaf spring by a motor driven mechanism, thus putting a load on the specimen, and the stress-strain curve is photographically recorded by utilizing an optical tripod movable about a fixed point — a device already incorporated in Chevenard's well-known differential dilatometer. Yield strength, tensile strength, and elongation can be measured accurately from the record film, owing to the clear definition of the line drawn on it. The three curves shown opposite give tensile results on three steels varying greatly in strength and ductility. Micro tests on homogeneous metal agree (within the expected scatter of results) with tests made on standard sized test pieces, which are about ten times as large in diameter.

For making the shear test the leaf spring has attached to it a clamp or vise with hardened faces which passes the 1.5-mm. rod through it, and the slightly protruding end is cut off by a shear blade (made of cemented carbide) attached to the movable lever. Of all the tests possible in the "micro-tester," this shear test appears the most appropriate for the mechanical exploration, almost point to point, for the entire specimen can be cut into tiny rods, and these sheared into bits 1.5 mm. long.

The writer, together with M. Chevenard, has described several series of tests on welded joints, made in the indicated manner, in a paper before the recent welding symposium held by the British Iron and Steel Institute. From these results, a pair of diagrams is reproduced below, showing the tensile and shear characteristics of a joint in $\frac{9}{16}$-in. chromium-molybdenum steel plate (carbon 0.31%, chromium 1.0%, and molybdenum 0.36%), oxy-acetylene welded with rod of the same metal.

Results of Micro Tests on the Cross-hatched Strip of Steel Cut From Weld in Cr-Mo Steel





Tensile Tests on Micro Test Pieces on Three Classes of Steel. Curve for steel 2 shows how tensile properties are measured. Shear curves have a shape similar to curve for steel 1 if it were stopped close to its maximum

It will be observed that there is a considerable decrease in tensile strength and yield point and a slight decrease in shear strength at the joint, with little change in the ductility. The depression in the strength curves discloses an overhardened condition in the fusion zone. About 1½ in. from a weld there is a very distinct minimum in strength, and gain in elongation. This softened zone is the effect of the heat of welding. A self-hardening effect is noted closer to the weld, more marked in joints in thinner gages.

The use of very small test pieces is not entirely new. Petersen in 1930 *Transactions* describes fatigue test pieces 1 to 2 mm. (0.04 to 0.08 in.) in diameter. It might be mentioned that the French Bureau of Aeronautics is planning to use similar small fatigue tests. We are also engaged in designing testing machines for micro impact pieces.

In conclusion, it may be pointed out that the use of micro test pieces has broad applications to theoretical study, especially of the influence of grain size, orientation, and boundary effects on the mechanical properties. In a more "practical" way, it may easily be possible to trepan small pieces from joints in a complicated structure, and thus prove their quality without in any way harming the completed work, since the small holes could easily be closed afterward.

ALBERT M. PORTEVIN.

New Viewpoint on the Origin of Flakes in Steel

SCHWEINFURT, *Germany* — The origin of flakes in steel has been an important problem to metallurgists for many years; therefore several recent articles which attribute the cause of flakes in steel to hydrogen have aroused great interest. Before they arrived at this new explanation, E. Houdremont and H. Korschan took into consideration the divergent views formerly expressed in the literature.

In order to differentiate clearly from many other defects which occur in steel, Houdremont and Korschan defined "flakes" as those defects that generally show a somewhat circular form, are of small surface extent, and have a fracture different from the usual grain structure of heat treated steel. Thus hair cracks, intercrystalline cracks, conchoidal fracture, quenching cracks, longitudinal and corner cracks in the cast ingot, and forging bursts are, among others, excluded. True "flakes" in this meaning of the term, are thus differentiated from the cracks running from grain boundaries, and which are caused by hot working. "Primary grain boundary cracks," on the other hand, are internal cracks running from the boundaries of primary grains in unworked castings or ingots.

A summary of the factors influencing the cause of flakes might be outlined as follows:

1. Stresses, caused by
   - *(a)* non-uniform cooling
   - *(b)* forming (residual working stresses)
   - *(c)* transformations
2. Metallurgical factors
   - *(a)* segregations
   - *(b)* inclusions
   - *(c)* gases

The possibilities contained in the foregoing outline have been extensively discussed in the literature. On the basis of extensive new experiments Houdremont and Korschan have arrived at the following conceptions:

Flakes occur not only in alloy steels (particularly chromium and chromium-nickel steels) but also even in unalloyed steels with carbon up to

0.20%. Tungsten steels appear to be particularly sensitive.

Insofar as the method of steel manufacture influences the formation of flakes, the new experiments showed that crucible steel, acid open-hearth steel, and acid high frequency steel are less sensitive to flake formation than basic open-hearth and basic electric arc melted steel. In acid steel flakes occur only in small number and to slight extent.

The ingot size is a factor; larger ingots have a greater tendency to flake formation.

Lower pouring temperature somewhat reduces the tendency; however, since the pouring temperature is less variable than other metallurgical factors, it has only minor influence. The pouring rate, on the other hand, has greater possibilities, for slow pouring results in less tendency toward flakes in the product than fast. A steel with about 0.25% C, 4% Ni, 1.5% Cr, and 1% W, poured into 12-in. round ingots, showed flakes when poured in 33 sec., but none when the pouring time was 80 sec. Indeed, slow pouring gives absolute security against flakes.

The characteristics of the ingot mold were also investigated, and it was determined that the *form* of the ingot did not influence the sensitivity of the steel to flakes. The character of the wall, or the mold wash, on the other hand, seemed to have great effect: Uncoated and graphite-coated molds produced a steel insensitive to flakes, while varnished or sprayed walls produced a steel sensitive to flakes, because, as was later shown, of hydrogen from the varnish coating (*Lackanstriche* is the word used in the original articles, and the nature of these coatings is not specified).

Ingot tops and centers tended more toward flakes than the bottoms. It does not follow from this that segregation and inclusions are responsible.

The temperature at which flakes form had not previously been fixed with any degree of certainty. New tests were therefore undertaken which indicate the region to be at about 400° F. Thus, flakes were found in chromium steel that was taken from the cooling furnace at 600° F. or even hotter, and in chromium-nickel steel taken from the furnace at temperatures above 400° F. However, samples of either of these steels taken from the cooling furnace between 200° F. and room temperature were free from flakes. These tests were repeated under different conditions and on other billets, and it was found that all samples which were even fairly rapidly cooled in air to above 400° F., put back into a furnace at or slightly above that temperature, and cooled quite slowly from 400 on down contained no flakes. Houdremont and Korschan therefore concluded that flake formation occurs in the neighborhood of 400 to 200° F.

From a practical standpoint it is particularly important to note that it is not the cooling speed from high temperature which is the determining factor in flake formation, but the speed with which the piece of steel is cooled through the lowest temperature range (about 400° F.).

On the basis of these experiments the question is again raised whether transformation stresses are the cause of flakes, or whether, as W. Eilender and H. Kiessler assume, forging strains must be added to the cooling and transformation stresses. Further tests showed that when the amount of forging was increased, the tendency to form flakes decreased, and that steel can be made flake-free with repeated forging, and with appropriate cooling will remain so.

In the opinion of Houdremont and Korschan, therefore, the "pure stress" theories are untenable; further that segregations, such as nonmetallic inclusions, are likewise not the governing factor.

Whiteley has expressed the opinion that over-oxidation of the molten steel is a prime cause of flakes. His viewpoint is that flakes are caused when the carbon monoxide formed from iron oxide and carbon in such poorly made steel cannot diffuse out of the steel as it rapidly cools — in other words, a localized, high internal gas pressure may rupture the material. Houdremont and Korschan do not agree with this viewpoint, because even with intentional over-oxidation and imperfect deoxidation they were unable to produce flaky steels when properly cooled.

Likewise dissociation processes, particularly the dissociation of nitrides and its related brittleness of steel, were not regarded as plausible explanations, in spite of the fact that acid steel containing less nitrogen contains fewer flakes than basic open-hearth and electric arc furnace steel with higher nitrogen content.

While the discussion so far has principally been of a negative character, I hope to outline, in a subsequent letter, the new experimental work of a number of German investigators which lends strong probability to the hypothesis that hydrogen is the cause of internal fractures (flakes) in steel billets or forgings, occurring in the steel when it is cooling from 400° F. to room temperature.

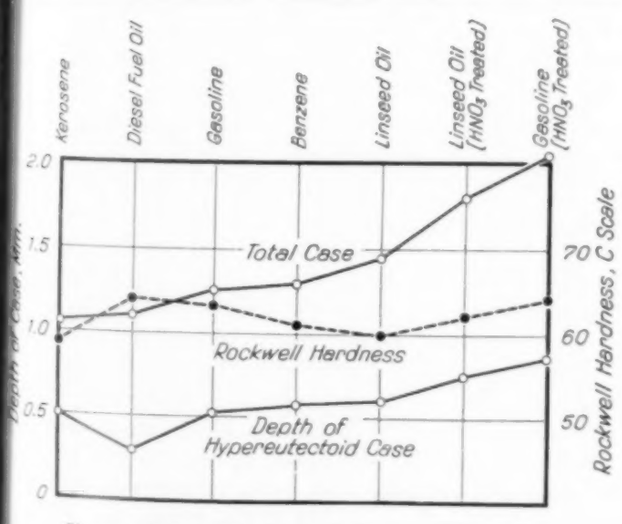
HANS DIERGARTEN.

Efficiency of Various Oils as Carburizers

GROSNY, *U.S.S.R.* — Case hardening of low carbon steel by carbonaceous gases, such as carbon monoxide, natural gas, butane, or manufactured illuminating gas (city gas) has many advantages over the use of solid carburizers. A number of papers printed recently in METAL PROGRESS have established these facts, and the gas carburizing process has been applied in numberless plants.

However, the process has one important disadvantage in many industrial regions in Europe, where an almost universal supply of gas (as distributed throughout the United States) does not exist. In such places it would be necessary to install a gas producer — an expensive proposition, especially for the smaller plants. This is one reason why solid carburizer is still the main reliance of European metallurgists.

We also know that a very successful furnace (electrically heated) has been promoted in America which carburizes steel by oil vapors, produced at a high temperature in the same retort in which the heated steel parts are carburized. The method is quite simple; the oil is introduced drop by drop from a mechanism similar to a common lubricator. Striking the hot furnace interior at about 1700° F., the oil breaks down into an extremely active carburizing medium. A fan circulates the vapors through the charge.



Characteristics of Carburized Case on Low Carbon Steel Made by Introducing Various Oils, as Noted, Drop by Drop Into the Hot Retort

It appeared to us that this scheme would give us the advantages of gas carburizing without the necessity of an expensive gas producer, so research was undertaken at the Moscow Steel Institute to determine the optimum conditions, limiting the study to the commonly available oils such as benzine, kerosene, fuel oil (diesel), gasoline (automobile fuel), and linseed oil.

It was quickly found out that many oils, in undergoing such decomposition by sudden heat, form a large amount of carbon black, which interferes with the carburizing conditions. In order to get rid of this it was proposed to decompose the oil in a separate steel retort in which the carbon black is to remain, while the produced gas is led into a second retort filled with steel parts for carburizing. It was also suggested that a special kind of catalyst be introduced into the operating space of the furnace in order to reduce or avoid the formation of carbon black. It was our effort, of course, to find out whether certain oils could be found which would not produce such a voluminous deposit of soot.

Moreover, the activity of various petroleum products and linseed oil, and mixtures thereof, was also investigated. It was discovered that the lighter the oil fraction (according to its specific gravity) the more active it is — that is, the quicker and better it carburizes. Linseed oil was found to be the most active of any common organic product, but its high cost made it necessary to look for a cheaper equivalent.

This solution of the problem was achieved after it was pointed out that the unusual activity of linseed oil might be due to the complex oxygen bearing molecules it contains (the content of oxygen in its ultimate analysis being the principal analytical difference). Following this clew, we treated (oxidized) various petroleum products with nitric acid, and found them to be considerably improved. In fact, gasoline, treated with nitric acid, was even more active than linseed oil, either as received or similarly treated.

Results of the tests are given in the figure. Conditions were the same in this series of tests, which is representative — a uniform load of steel parts carburized 5 hr. at 1750° F. At the end of the run depth of the case was measured on a fractured surface, the hyper-eutectoid shell measured under a microscope, and the hardness (Rockwell C) taken of some quenched samples.

Following these investigations, carburizing with treated gasoline has been conducted successfully on a commercial scale in our country.

B. M. SUSLOV

Cost of Stainless Ware

AKRON, *Ohio* — An editorial in March METAL PROGRESS commented on the high cost of domestic articles made of stainless steel, a matter which anyone can verify by comparing department store prices of simple spun shapes like mixing bowls. The price of the stainless articles is so much greater than the price of aluminum or enameled iron that few housewives will purchase.

It had been my remembrance that retail prices charged in England were more nearly competitive, and this is confirmed by a large advertisement appearing in the current issue of "Over-Seas Daily Mail" of J. & J. Wiggin's tableware made from Firth Vickers "Staybrite" steel (16% chromium, 10% nickel). Altogether, about 125 articles are illustrated. Representative prices, translated into dollars at the rate of 1 shilling to 24c, are: Egg cups, 60c each; sandwich plate with handle, $2.15; complete tea service and tray, $22.00; toast racks, 85c; sauce boats, $2.00; 8-in. plates, $1.50 each; grapefruit or sundae cups, $1.20 each. These prices are on the same order as copper or chromium plated brass articles on the American market.

Toasters at 75c each should not be quoted without noting that they are an English institution. A toaster consists of a long handle extending from the back of a rectangular plate. On its front is a number of spikes, and you impale a slice of bread on them and hold it in front of an open fire. Eventually you get some toast.

PAUL D. FFIELD

"Queensway" An Example of Metal Progress

LIVERPOOL, *England* — For an Englishman to talk to the great nation that produced the Holland Tunnels and the numerous other rapid transit tunnels under the Hudson and East Rivers about another and greater under-water tunnel for automobile traffic savours of unimaginable impertinence! My excuse for so doing, however, is that "Queensway," the wonderful new Mersey tunnel, is an epoch-marking achievement in the progressive history of engineering, and that from end to end this great work is literally one long and outstanding example of metal progress in its most up-to-date form.

It is truly without parallel throughout the entire civilized world. Its length of roadway, from Old Haymarket, Liverpool, to Chester Street, Birkenhead, is 2.13 miles. Its width between curbs is 36 ft., thus handling four lines of vehicles, instead of the double line in notable American tunnels. 82,000 tons of cast iron was used in lining and for paving; a million bolts were used to hold the cast iron lining segments together.

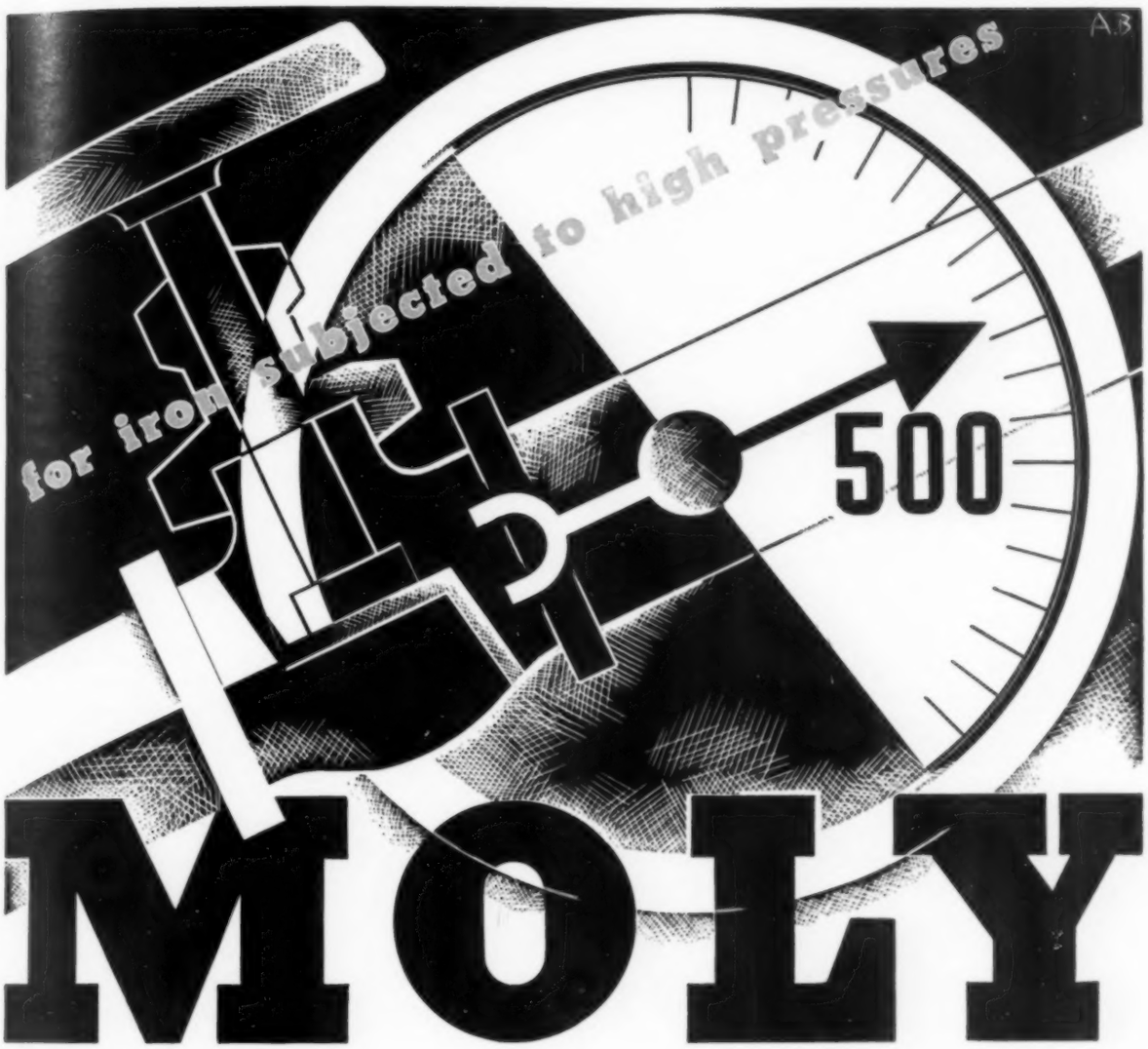
An innovation in the tunnel roadway is that it is constructed of non-skid cast iron blocks which are easily cleaned and repaired. The units are hardened by a special process to increase resistance to traffic wear and tear, and are laid on the concrete foundation and joined by bituminous cement.

As is doubtless well known, sub-aqueous tunnels are round in cross-section and are shield driven, a segmental lining being erected and bolted together behind the excavating chamber in the shield as it is forced forward. The under-water section of the Mersey tunnel is approximately one mile long. While the tunnel is lined throughout with cast iron segments, in the under-water section steel joists are used in addition. These are curved to fit the arch, and are encased in the concrete inner lining at intervals of 30 in. They assist in resisting the pressure of the semi-fluid surroundings.

Inside this circular tube are placed roadway and ceiling, with large passages next the lining for ventilation. Decorative, easily cleaned walls are also desirable.

Reinforcements for walls, ceiling, and road are of steel, anchored to the cast iron lining. The walls themselves are based on concrete foundations laid on the cast iron segments in the lower half of the tunnel. At either side are foot-paths. Under them are conduits for light, power, telephone, and signal systems. Cast iron curbs protect these foot-paths from wheeled traffic. Appropriate openings in these curbs connect with the fresh air supply.

In place of the small tile usually seen in subway linings, the Queensway is lined with glass. Black glass in the form of a dado rises to a height of 6 ft. 3 in. from the concrete plinth level; it consists of three graduated rows of glass in large sheets ¼ in. thick, laid in lead cames or munting and framed outside with bars of stainless steel. Both of these metals are unaffected by water or fumes. The lead supports are also held with special rails of non-ferrous metal. These rails have a movable web at the front, and two contact cushions at the back; thus the glass is held firmly in position. The supporting rails are driven into lead plugs, inserted in the concrete facing, driven in by *(Continued on page 56)*



ADVANCING civilization has ever demanded inventions and mechanical improvements to meet its faster economic pace and higher industrial standards. Greater speed — in transportation and in production — has put heavier strains on machinery . . . which in turn, have put higher pressures and other stresses on the irons and steels going into their construction.

For example, more and more is being demanded of such iron castings as Diesel and gasoline engine liners, valves, cylinder blocks, condenser heads, etc. *The most economical and efficient of all methods for meeting the increasingly stringent specifications is by resorting to a Molybdenum-alloyed gray iron.*

Example: A concern producing cast iron steam valves had been using an alloy iron (with no "Moly") which passed the 250 lbs. test against leakage, but almost invariably permitted leaks at 350 lbs. They changed the alloy content to .45% Moly and .25% Chrome — cutting their alloy cost from .62c per pound to .45c per pound — *and the valves did not leak even at 500 lbs. pressure.*

Moly is gaining more and more the reputation as the outstanding alloy element of the age. Keep up to date with the developments that are constantly making progress . . . let us put you on the mailing list of our periodical news sheet, "*The Moly Matrix.*" And, while you are sending us your name and address for this purpose, your further request for these two books will be gladly complied with: "*Molybdenum in* 1934" and "*Molybdenum in Cast Iron* — 1934 *Supplement.*" Still further, if you've an alloy problem that's hard to solve — either from an economy or an efficiency standpoint — our metallurgists and Detroit laboratories are at your disposal. Climax Molybdenum Company, 500 Fifth Avenue, New York City. (In Canada: Railway & Power Engineering Corp., Ltd.)

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Correspondence

(Cont. from page 54) pressure to a minimum depth of 2 in., and protruding from the face $\frac{5}{8}$ in. This is to provide an insulation space between the concrete lining and the back of the glass, to allow variation of alignment to be overcome, and to prohibit slight movements of the main structure being transferred to the glass. The support is designed so the glass is easily replaceable in sections; any seepage of water can also drain away at the road-level. The glass is easily cleaned, and the cost of maintenance is a most insignificant factor.

Stainless steel was used in a number of other places in the tunnel, where complete resistance to fumes and damp were required. These include exposed bolts and nuts, name plates, signs, manhole covers, and some bare, inaccessible structural members subject to corrosion.

Fine examples of the almost vanished art of decorative iron casting are the walls of the toll booths in the various entrance plazas.

F. G. Martin

Plating Reflectors With Indium

Glasgow, *Scotland* — It is doubtful if any of the rare metals will not have received commercial application before many years have elapsed, and one of the latest additions to this list is that of indium. At present, it represents one of the most precious metals, and hitherto has been regarded as a scientific novelty. Yet it appears to have great possibilities as a reflecting medium.

Within the past few years several patents have been taken out in England and elsewhere on the plating of reflectors with platinum-iridium and platinum-rhodium alloys. Reflectivity of these deposits far surpassed earlier mirrors of the platinum group. Research work has proved, meanwhile, that numerous small practical difficulties arise when dealing with the platinum metals. For example, an excessive addition of rhodium to the deposit directly lowered the coefficient of reflection, and produced a dulling effect on the mirror.

No such difficulty is experienced with indium, which does not require the assistance of other metals. It reflects light in a manner hitherto unknown, and with a *(Continued on page 58)*

BEHIND THE SCENES OF INDUSTRY

From plowing to harvesting—parts for all types of farm machinery are processed in Mahr Furnaces.

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Tractor shoes are about to be annealed in the car type furnace illustrated at the right.

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Upon request we would like to send you illustrated folders showing the part Mahr Furnaces play "Behind the Scenes of Industry."

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Murex Mineral Coated Electrodes make it easy to obtain weld metal to fit almost any specified requirement . . . not only in tensile strength, but in other physical properties and in chemical analysis as well.

The wide range of properties available is shown in the illustration above. The four all-weld metal Standard Tensile Test Specimens in the foreground, reading from left to right, tested as follows:

1. MILD STEEL SPECIMEN

Tensile Strength	64,500 p.s.i.	Reduction in Area	65.9%
Yield Point	53,500 p.s.i.	Elongation in 2 in.	37%

2. HIGH CARBON STEEL SPECIMEN

Tensile Strength	73,000 p.s.i.	Reduction in Area	63.5%
Yield Point	59,000 p.s.i.	Elongation in 2 in.	31%

3. 2½% NICKEL STEEL SPECIMEN

Tensile Strength	86,000 p.s.i.	Reduction in Area	64%
Yield Point	72,000 p.s.i.	Elongation in 2 in.	25.5%

4. CROMANSIL STEEL SPECIMEN

Tensile Strength	100,000 p.s.i.	Reduction in Area	55.5%
Yield Point	85,750 p.s.i.	Elongation in 2 in.	22.5%

The Murex line includes electrodes for high speed, down-hand welding of mild steel; for three position and horizontal fillet welding; for welding manganese, stainless, carbon-molybdenum, Cor-Ten, Mayari, Cromansil, copper-bearing, high carbon, and nickel steels; and for building up and hard surfacing plain carbon steels. All are standard Murex Electrodes that can be furnished promptly from stock . . . and, all possess the well known Murex ability to provide highest quality weld metal at lowest cost.

A newly published booklet gives complete data on the chemical analysis and physical properties of the metal deposited by each electrode in the Murex line. Write for Booklet 2 a. p.

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Albany Chicago Pittsburgh S. San Francisco Toronto

M U R E X
HEAVY MINERAL COATED ELECTRODES

Correspondence

(Cont. from page 56) faithfulness which has not so far been observed in any of the plated metals.

The high market price of indium is largely due to the fact that no commercial application has been found for it, for even ordinary zinc contains minute proportions of this element, and traces are present in numerous ores and metallurgical products.

Most of the earlier research workers extracted the metal by sulphide separation followed by precipitation as basic sulphide, using sodium bisulphite as the reagent. This overlooked the more direct barium carbonate system, which had not at that time been properly applied.

The position of indium in the electrochemical series of the elements is between that of thallium and lead, and hence it is a simple matter to deposit it electrolytically. The plating of reflectors does not call for any large amount of metal to be deposited, and this gives scope for the rarest of elements to be utilized. The important point where most electrodeposits fail is in the reflection of colored light. This is one of the features of the recent indium deposits, as an exceedingly thin coating of the latter metal reflects the various bands of light in the spectrum in the most efficient manner.

Indium is deposited from either sulphate or chloride solutions, but the addition of selected colloids to restrain crystal growth is a necessity. Pyridine, hydroxylamine, certain gums and extracts are used in this capacity.

The future of reflectors plated in this manner will largely depend on the economical extraction of the rare element itself. It is believed that reflectors for searchlights may be measurably improved by a very thin deposit of this rare metal.

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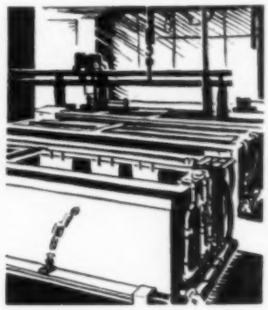

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Chromium Plate on Sewing Machine Parts, F. B. Jacobs, Metal Industry, June, p. 209.

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FREE LITERATURE

Nickel Scrap

Cosmo Metal Alloys has issued a useful reference booklet listing a wide range of nickel and nickel alloy secondary metals valuable as scrap. It is a useful guide to those using nickel and its alloys in any form. Bulletin Jzx-31.

Tool Steel Selector

A wall chart, 30 x 20 in., to be used as a means for selecting the proper type of tool steel is offered by Carpenter Steel Co. to tool steel users in the U.S.A. only. Bulletin Jzx-12.

Intergranular Corrosion

Electro Metallurgical Co. tells how the addition of columbium to the austenitic type of stainless steel eliminates intergranular corrosion. Data are given on physical properties and corrosion resistance of columbium-treated steels. Bulletin Jzx-16.

Textile Equipment

Republic Steel Corp. made an extensive survey of the textile industry. The very interesting results are reported in a folder which shows in color the effect of stainless steel and other equipment materials on dye colors. Bulletin Jzx-8.

Carburizing Shop Practice

H. W. McQuaid's discussion of gas carburizing shop practices published in Metal Progress last year is reprinted in handy folder form by Surface Combustion Corp. Bulletin Jzx-51.

Silico-Manganese Steel

Silico-Manganese steel for heavy duty springs is the subject of Bethlehem Steel Co.'s new folder giving its properties and recommendations for heat treatment. Bulletin Jyx-76.

Electric Furnaces

The electric furnaces made by Hoskins Mfg. Co. are well presented in their latest catalog. Contents include data on 17 types of furnaces and some valuable information on Chromel resistance wires and thermocouples. Bulletin Sp-24.

Metameter

Information on Bristol Co.'s Metameter, which makes it possible to control temperatures, pressures, levels, and other process conditions or operations at any distant place, is contained in Bulletin Ax-87.

Carburizing Retorts

Low cost, flexibility, uniformity, control, quality, and less labor with retort gas carburizing, says American Gas Furnace Co. Rotary, vertical and bell type retorts are described in Bulletin Jyx-11.

Phosphor Bronze

An interesting little history of bronze from antiquity to the present prefaces a complete description of the properties, composition, uses, and shapes available of Seymour phosphor bronze in a folder by Seymour Mfg. Co. Bulletin Jyx-48.

Safety in Oxwelding

A revised edition of "Precautions and Safe Practices" in the care and handling of oxy-acetylene equipment has been prepared by Linde Air Products Co. This booklet is regarded as a standard reference on this phase of safety in industry, and this latest edition contains some new suggestions required by advances in the oxy-acetylene process. Bulletin Mx-63.

Electric Furnaces

A wealth of information on controlled atmosphere electric furnaces is contained in General Electric Co.'s booklet by that name. Detailed data are given on electric brazing in particular. Bulletin Jx-60.

Special Bronze

American Brass Co. tells why Anaconda "Special" phosphor bronze can be used advantageously for bushings, bearings, gears, and other screw machine products. It is a truly free-cutting alloy and does not foul cutting tools. Other properties are given in this new edition of their booklet. Bulletin Fx-89.

Burners and Valves

Auxiliary equipment for industrial furnaces that will insure proper heat production and correct combustion, such as oil and gas burners, blowers, regulating and shut-off valves, is fully described in Mahr Mfg. Co.'s illustrated booklet. Bulletin Jyx-5.

Metallographic Polishing

The Guthrie-Leitz automatic polishing machine is designed to eliminate all elements of the human equation which make the hand preparation of metal specimens so undependable. Described in Bulletin Jyx-47.

Screw Machining

Screw machine products of aluminum are treated in authoritative and extensive manner in a booklet of Aluminum Co. of America. Besides general data on screw machining, a number of very useful tables appear. Bulletin Ar-54.

Bright Annealing

Electric Furnace Co. tells about their controlled atmosphere furnaces for continuous deoxidize annealing, bright normalizing and annealing ferrous and non-ferrous metals. Work comes clean, bright and dry from these furnaces. Bulletin No-30.

Welding Electrodes

Electrodes for welding alloy steel, particularly "Cor-ten" steel, used for railroad cars and outdoor structures, are described in Metal & Thermit's new booklet. Bulletin Myx-64.

Rockwell Tester

The Rockwell Superficial Hardness Tester is applicable to far thinner sheet and strip than the regular Rockwell. Its use for nitrided and case hardened parts is also described by Wilson Mechanical Instrument Co. in Bulletin Myx-22.

Neophot

"Neophot" is the name of a new metallograph of radically new design and universal adaptability. A pamphlet distributed by Carl Zeiss, Inc., gives its applications and features and is well illustrated with beautiful samples of micrographic work. Bulletin Jx-28.

Recuperators

Results obtained with Carborundum Company's recuperators using Carbofrax tubes are fuel savings, closer temperature control, faster heating, and improved furnace atmosphere. Complete engineering data regarding application to various types of furnaces are given in Bulletin Fx-57.

Sheffield Steels

Wm. Jessop & Sons, Inc., have a leaflet which tells why a special anneal and a proper balancing of carbon, manganese and tungsten combine to make Sheffield Superior oil hardening steel non-distorting and easily machinable. Bulletin Jn-61.

Carburizing Boxes

Driver-Harris Co. devotes a folder to Nichrome cast carburizing boxes. Physical properties at room temperature and under operating conditions are given, as are the advantages of Nichrome castings for such service. Bulletin Jr-19.

Centrifugal Compressors

B. F. Sturtevant Co. has a line of centrifugal compressors designed particularly for industrial furnace applications. These are illustrated and described in Bulletin Myx-58.

Tubing Weight Tables

Timken Steel & Tube Co. has issued a series of "Master Weight Tables" for round steel tubing, on letter size heavy paper, punched for binding. Weights per lineal foot of length are given for all sizes of hot finished and cold drawn tubing. Bulletin Mx-71.

Heat Treating Manual

A folder of Chicago Flexible Shaft Co. contains conveniently arranged information on heat treating equipment for schools, laboratories and shops, and also illustrates the several types of Stewart industrial furnaces. Bulletin Ar-49.

Welding Design

Valuable technical information on the design of such parts as wheels, levers, bosses, and machinery bases for arc welded steel construction is contained in a series of "Application Sheets" issued by Lincoln Electric Co. Bulletin Myx-10.

Tempering Furnace

Technical details and operating data on Lindberg Steel Treating Co.'s new Cyclone electric tempering furnace, which has shown a remarkable performance record in steel treating operations, are given in Bulletin Fx-66.

Testing with Monotron

Shore Instrument & Mfg. Co. offers a new bulletin on Monotron hardness testing machines which function quickly and accurately under all conditions of practice. Bulletin Je-33.

Turbo Compressors

The new items in Spencer Turbine Co's bulletin are a new and smaller "Midget" turbo for individual mounting, a single-stage line which effects new economies, and the gas-tight turbos for acid and explosive gases. Bulletin Mx-70.

Radium Radiography

Advantages of portability, ease of application and manipulation in examination of castings, forgings, molds, weldings, and assemblies are attributed to radium for industrial radiography. Details are given in a booklet issued by Radon Co. Bulletin Jx-56.

Liquid Carburizing

E. F. Houghton's Perliton liquid carburizer is the subject of a 23-page booklet. Depth of case, speed of penetration, and other results are well illustrated with graphs and photomicrographs. Nv-38.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is usual. Bulletin Fe-13.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Blast Cleaning

A centrifugal machine which cleans castings without the use of compressed air is the subject of Pangborn Corporation's new folder. How and why 1800 lb. of castings can be cleaned in 8 min. at low cost is told. Bulletin Jx-68.

Moly Matrix

Climax Molybdenum Co.'s little monthly newspaper contains many interesting and informative articles. Get the latest issue by asking for Bulletin Ax-4.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Low-Cost Controller

Leeds & Northrup has a new low-cost Micromax controller for use where simple "on-off" control is adequate without indication or record, and where first cost must be low. Described in Bulletin Myx-46.

Misco Alloys

Compositions, properties, and applications of Misco stainless, heat, and corrosion resisting castings are given in an illustrated folder offered by a pioneer producer, Michigan Steel Castings Co. Bulletin Mx-84.

Free Cutting Steel

Jones & Laughlin Steel Corp. has published in attractive booklet form a record of 15 years of research by their metallurgical department into the machinability of free cutting steels. Bulletin Ob-50.

Hardening Furnaces

The C. I. Hayes Certain Curtain electric furnace for the range 1200 to 1850° F. is described in this bulletin. Its applications to hardening of carbon, stainless, and alloy tool steels and to preheating high speed steel are discussed. Nv-15.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. Bulletin S-27.

Steels for Automobiles

The story of "Cold Finished Steel and the Automobile" is very interestingly told by Union Drawn Steel Co. Improvements in automotive design are reflected in improvements in cold drawn steels, the advantages of which are now available to many other industries. Bulletin Ax-83.

Alloy Castings

A new bulletin on corrosion and heat resisting alloy castings is offered by Michiana Products Corp., manufacturers of Fire Armor and Zorite and other heat and acid resisting castings. Bulletin Jyx-81.

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Unique features of Foxboro pyrometer controller which give it high sensitivity, essential for good control, are given in Bulletin Mx-21.

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Reading for May

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Fabrication of Steel Garden Furniture, B. K. Price,

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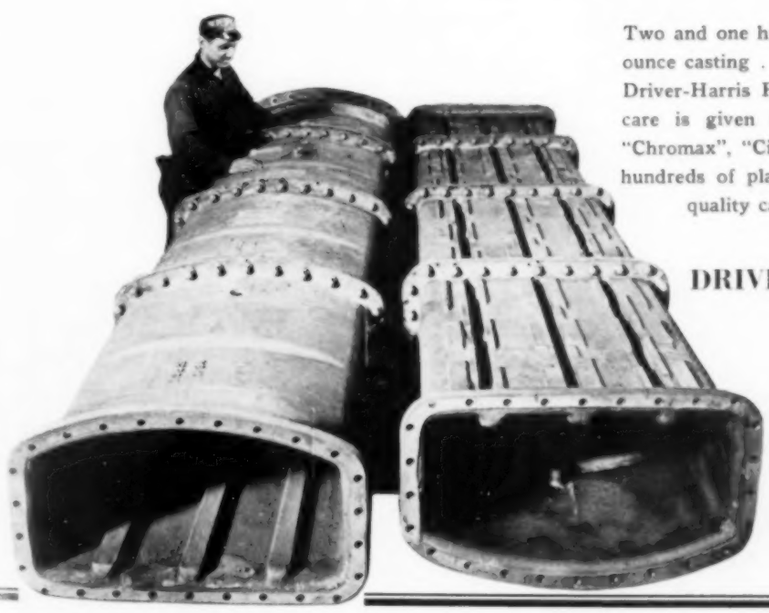

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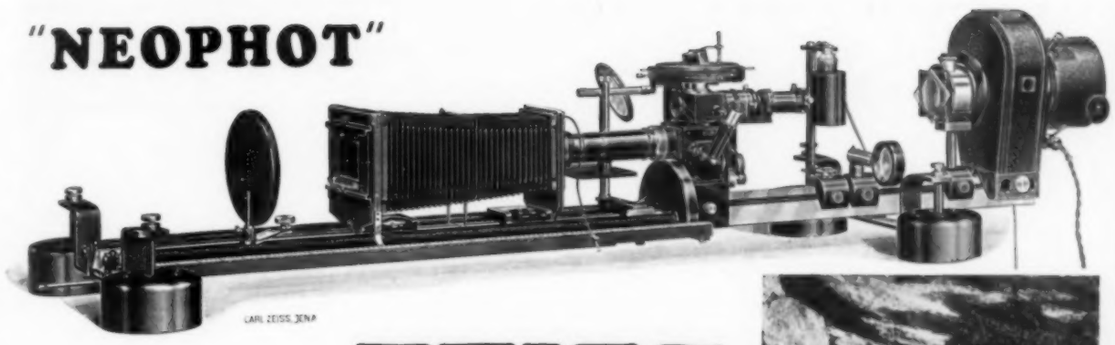
"NEOPHOT"



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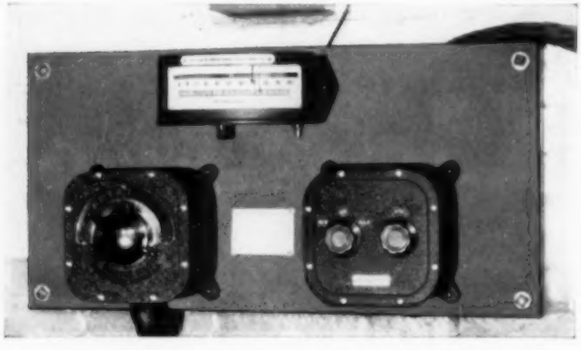

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